# Weatherwise

Volume 14
Number 5
October 1961

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

# WEATHERWISE

THE MAGAZINE ABOUT WEATHER

DAVID M. LUDLUM, *Editor* HENRY W. BULKLEY, *Associate Editor*

## Waiting for the Chinook

In 1886 Charles M. Russell was an unknown "range rider" in the employ of Stadler and Kaufman, large cattlemen. He made his first appearance by painting the picture which is reproduced on our front cover. This characterized him as the "cowboy artist" and subsequently the most famous artist of his type in the world.

"Waiting for a Chinook" depicts an interesting story. During the winter of 1886 there occurred one of the most severe snowstorms in the history of Montana. Cattle and sheep died literally by the thousands. Becoming alarmed, Russell's employers wrote him as to the condition of their stock in his charge. He did not write, but with his brush sketched a water color telling its own story. The coyotes awaited the last victim of the storm. The picture became famous and is the most noted of all of Russell's works. Charles Russell died at Great Falls, Montana, 24 October 1926, at the age of 61 years. A museum of his works is now maintained at Great Falls. Cover reproduction courtesy of the Hammer Galleries, New York City.

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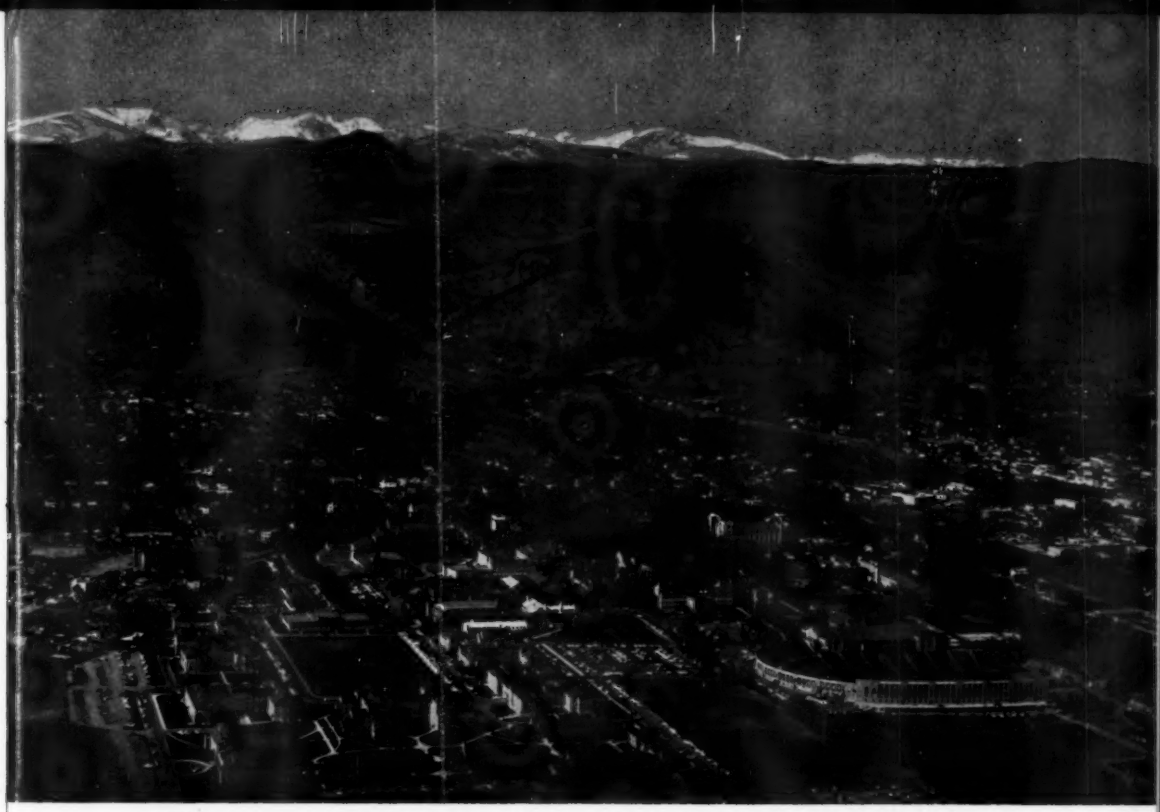

Chinook country at Boulder, Colorado. University of Colorado campus lies in foreground with the foothills of the Rocky Mountains to the west and the snow-capped Great Divide in the far background. Boulder is the home of the National Center for Atmospheric Research. Courtesy of the Boulder Chamber of Commerce.

# The Chinook

CHESTER L. GLENN, *Research Forecaster, U. S. Weather Bureau, Denver, Colorado*

THE chinook wind has played its part in the legend of western United States, and the name has become known across the country, even though the phenomenon itself may be only dimly understood. Charles Russell's painting "Waiting for a Chinook", showing a nearly starved steer standing in deep snow unable to find food, has become almost a symbol of old-time western ranching, and it has served to spread the fame of this warm wind which clears the ground of snow in some of the ranching area of western North America. Chinook is the name given in America to the more general "foehn" wind of Europe, which has been given a variety of names in other parts of the world.[1]

The foehn wind was known in Europe long before America was discovered, and refers to a warm dry wind blowing down the slopes of a mountain range, particularly of the Alps. Here in America this same type of wind has been renamed for the Chinook Indians and

[1] The *Glossary of Meteorology* lists the following local varieties of the foehn or chinook wind: *zonda* of the Argentine (for a westerly foehn); *puelche* in the Andes (for an easterly foehn); *ljuka* in Carinthia (northern Yugoslavia); *halny wiatr* in Poland; *austru* in Romania; *favogn* in Switzerland. A northeast foehn descending the Massif Central of France and extending over the Garonne plain is locally called *aspre*. A dry wind from northwest descending the coastal hills in Majorca is named the *sky sweeper*. In New Zeeland a foehn blowing from the New Zeeland Alps onto Canterbury plains is the *Canterbury northwester*.

generally refers to a wind from a westerly direction blowing down the slopes of the north-south ranges of western North America, generally the east slope of the Rockies. At times when the Great Plains area is covered by an extensive layer of cold air, banked up on the west against the Rocky Mountains, spectacular temperature rises may take place as this air begins to move out and is replaced by warmer air that has moved in from the Pacific area on westerly winds. As this Pacific air moves down the east slope of the Rockies, it is warmed and dried by compression effects, so is very effective not only in melting the snow cover very rapidly, but also in evaporating both the snow and the water from melted snow. The result is a rapid change from snow cover to bare ground in areas affected by this wind. The chinook wind is most prominent in what is sometimes known as the "chinook belt"—a narrow zone only two to three hundred miles wide just to the east of the Rocky Mountains, extending from Alberta southward through central Montana, across eastern Wyoming and Colorado, and into northeast New Mexico.

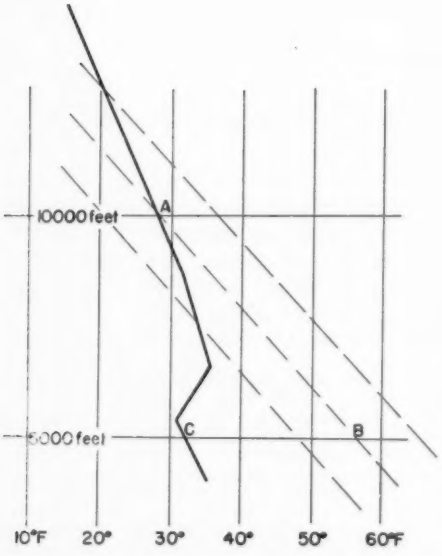


FIG. 1. Example of a temperature vs. height curve for a polar air mass in winter.

## THE FIRST FACTOR

The warm chinook wind obtains its heat from several sources. One of these is compression. It is a well-known fact that, if air is expanded, it cools—if it is compressed, it warms. We also know that the pressure of the atmosphere at high levels is much lower than it is at the surface of the ground. If air could be brought from a higher level down to a lower level, it would experience an increase in pressure with a resulting compression of its volume into a smaller space. This would be accompanied by warming, at a certain definite rate, known as the dry adiabatic lapse rate. A parcel of air which is lifted will expand and cool at this same rate—about 5.5° F for each thousand feet that it is raised, and conversely, a parcel of air which is lowered will warm at this rate. Figure 1 is an example of an air mass such as might be found anywhere in the United States in winter, showing how temperature changes with elevation. The dashed lines are those along which the temperature changes with elevation at the dry adiabatic lapse rate of about 5.5° F per thousand feet. If some of the air mass of figure 1 at 10,000 feet (point A) were lowered, say down a mountain slope to 5000 feet, its temperature would follow line AB reaching B at the 5000-foot level, which is much warmer than point C, the temperature of the actual air at this elevation. It is the case with almost all air masses, that if air from aloft could be brought to the ground, warming would result.

## THE SECOND FACTOR

A second factor which at times is very important in chinook warming is the addition to the air of latent heat of condensation. We all know that if we put a container of water on a hot stove, the water will be eventually boiled away. Heat from the stove is added to the water in order to cause it to change to invisible water vapor. If this process could be reversed and the water caused to recondense, this heat (the latent heat of condensation) would be regained, and would be used to heat the surroundings. This process does take place in nature. If air containing invisible moisture moves from the Pacific area up the west slope of mountain ranges of

western United States, clouds form and rain or snow falls in and west of the mountains. Part of the moisture which was formerly invisible has been condensed and removed from the air. If the air is now returned to its starting elevation, it will be found to have gained heat from the precipitation process, and will now be warmer than when it started. At one time it was thought that precipitation on the windward slopes of the mountains always accompanied chinook warming, and in the case of the European foehn this may be true. However, in America well-defined chinooks occur either with or without this precipitation to windward.

## THE THIRD FACTOR

Another factor is of utmost importance in chinook warming. Suppose the region east of the Continental Divide is covered by an extensive high pressure area involving a cold mass of polar or Arctic air. This cold air has a very definite depth. The portion near the center of the high pressure is deepest, and the depth tapers off from there outward, becoming zero somewhere in eastern United States at the cold front which marks the advancing boundary of the cold air. To the west the cold air banks up against the slopes of the Continental Divide in much the same

FIG. 2. East-to-west cross-section showing cold air banked up against Rocky Mountains.

way that fluid in a shallow dish intersects the tapering sides of the dish. Weather stations at the lower elevations and within the cold air will have considerably colder temperatures than those in the warmer air at higher elevations. Figure 2 is an imaginary cross section showing how this shallow cold air lies over the Plains area and up against the mountains. Figure 3 presents a weather map showing typical pressure systems in such a case. The boundary of the cold air is marked by the cold front to the east and south where the cold air is still advancing, and a stationary front along the Rockies where the edge of the cold air has become nearly stationary.

The behavior of the cold, dense, Canadian air is not too much different from that of any other fluid, such as water. A large mass of this fluid air material flows down out of Canada, spreads southward and eastward across the United States, and fills up to a certain depth along the Divide. Eventually the major part of the cold air has moved in.

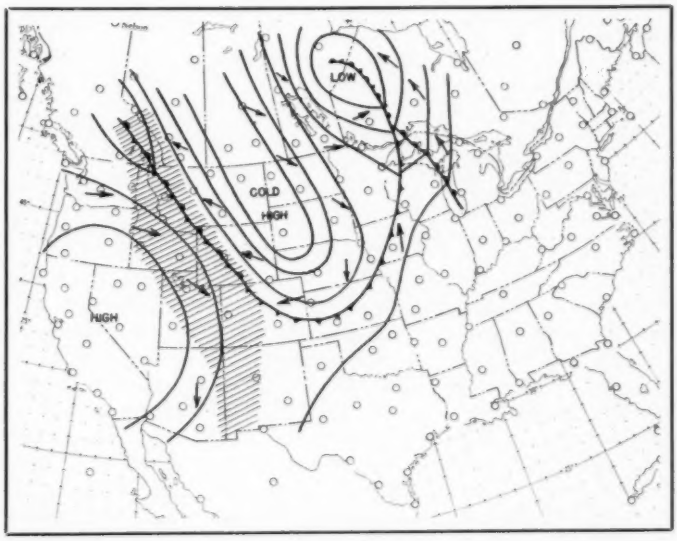


FIG. 3. Representative weather map showing cold polar air mass moving into area east of the Rockies.

It becomes stationary for a time, the dome-shaped top flattens out, and it becomes shallower as its area gradually spreads. As the level begins to drop, some of the places near the edge will be released from the grip of the cold air, but it is also possible for various disturbances to cause the cold air to undulate up and down. This may cause drastic temperature changes at places that are alternately in-and-out of the sea of cold air. Some extreme examples of this sort of thing will be described later. Eventually, low pressure will form in the chinook belt just east of the Rockies; due to its position with respect to the mountains, this is a favored position for lows to form when the upper winds are from west to east. The presence of this low forces the high with its cold air eastward into the plains, leaving at least part of the chinook belt under the influence of warm westerly winds, blowing down the slopes of the Rockies. This situation is shown in figure 4 and represents conditions a day later than figure 3. Winds tend to blow counterclockwise around a low, but with a strong turning inward—say about 40 degrees. With this in mind it can be seen from figure 4 that areas west and south of the low are under the influence of westerly winds which are blowing down the east slopes of the Rockies. The formation of this low with its westerly winds, assists the warm air in pushing back the cold air and results in areas in the chinook belt changing from a cold Canadian air mass to a much warmer one that originated over the Pacific Ocean. This adds a third factor—change of air mass—to the previous two factors involved in chinook warming (the compression effect, and the latent heat of condensation).

## THE FOURTH FACTOR

There is still a fourth factor that has some influence on the chinook warming process which affects only the nighttime temperatures. Normally on a clear night the ground cools rapidly by radiating heat off into space. Contact with the cold ground produces most of the nighttime cooling of the air with which we are familiar. This contact cooling can affect only a rather shallow layer, say a few hundred feet in depth, while the air at higher elevations than this remains fairly close to the temperature that it had during the day. If a wind, such as the chinook wind, is blowing, turbulence produced by the wind blowing over the rough ground surface, causes quite thorough mixing of the lower layers of air, and does not permit the shallow cold layer to gather at night, thus keeping minimum temperatures at a rather warm level.

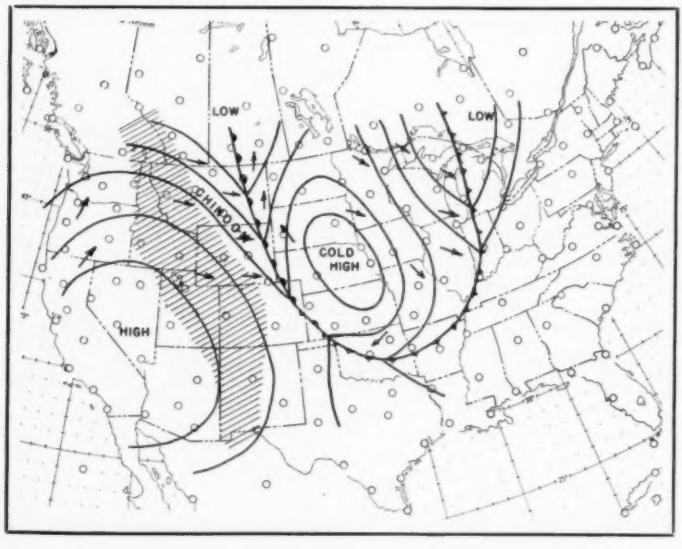


FIG. 4. Representative weather map twenty-four hours later than Fig. 3, showing the cold high pressure area displaced eastward away from the mountains and chinook winds blowing west-to-east down the slopes of the Rockies.

This factor will, of course, not be effective in raising daytime temperatures.

Four factors in chinook warming have now been discussed—compression, latent heat of condensation, displacement of cold air by warm air, and nighttime mixing. Not all of these factors might operate in every situation, but the chinook is distinguished by the fact that it obtains some of its warming from downslope motion. How strong the wind must be or how far the wind must move downslope before it can be properly called a chinook has never been answered, and it must be recognized that there is no sharp dividing line between a chinook situation and one in which the warming is not a result of chinook. It is not surprising then that residents of the chinook belt call any westerly wind that brings abrupt warming, a chinook. Some interesting illustrations of the source of warm air in chinook situations has been given by Cook and Topil (1).

## THE BLACK HILLS CASE

A good example of the difficulty in nomenclature is illustrated by the situation that occurred along the Black Hills of South Dakota in mid-January of 1943. This interesting case appeared in the *Monthly Weather Review* for March 1943 (2), and is no doubt one of the most striking cases of temperature change ever recorded in the United States. Residents and newswriters of the area generally considered this one of the most amazing "chinooks" they had ever witnessed. However, no very great amount of the warming could be attributed to downslope motion, even though moderate to strong westerly winds did blow, so meteorologists are reluctant to call this a true chinook. Nevertheless, the story is of such interest that we shall defer to the opinion of the local residents and discuss this event as though it were a true chinook.

On 15 January 1943, an outbreak of extremely cold Arctic air moved into the Great Plains, covering the Black Hills area and producing in many places record low temperatures. Starting on January 20th, the cold air became shallow enough that some of the mining towns at the higher elevations in the Black Hills began breaking through into much warmer air. During the day of January 20th warming occurred at all points above 4500 feet, and during the next two days warm air aloft scoured out another thousand feet of cold air, at least in the southern hills, but left places below 3500 feet still in the grip of some of the coldest weather on record. The change in temperature was really extreme, ranging from readings below zero in the cold air to as high as +60° F in the warm air. On January 22nd some minor pressure disturbances moving through the area caused the cold air to undulate up and down like waves against a wharf after a speedboat passes. The phenomenon was first noted at Spearfish, South Dakota, at 0732 when the mercury skyrocketed from −4° F to +45° within a period of only two minutes. This was only the beginning of a series of sharp dips and rises that continued for an hour or two. As time passed, the phenomenon progressed southward, reaching Rapid City by mid-morning.

At 0530 in the morning the city office temperature at Rapid City was −5° F—by 0940 a west wind set in and the temperature soared to +54°. Less than an hour later, with the west wind subsiding, the mercury slumped to +11°, then 15 minutes later rose to +55° at 1045. By 1130, only 45 minutes later, the cold air returned to drop the reading to +10°. After another rise-fall-rise, the temperature at 1600 stood at +56°, only to tumble to +5° at 1930 that evening.

With such extreme changes in short periods of time, one can imagine what great differences must have existed over short distances. It was reported that while the temperature at Lead, South Dakota, was +52°—at Deadwood, only three miles away but at a 600-foot lower elevation, it read −16°. Changes in temperature were so rapid that plate glass windows were cracked in downtown Lead.

## THE HAVRE CASE

The episode just recounted is no doubt one of the extreme examples of temperature change that has occurred anywhere. A similar, but less spectacular event in December 1933 was studied by Frank A. Math when official-in-charge-of the Weather Bureau Office at Havre, Montana. Here the temperature fluctuations took place over the period of a week rather than in a single day. It is more-

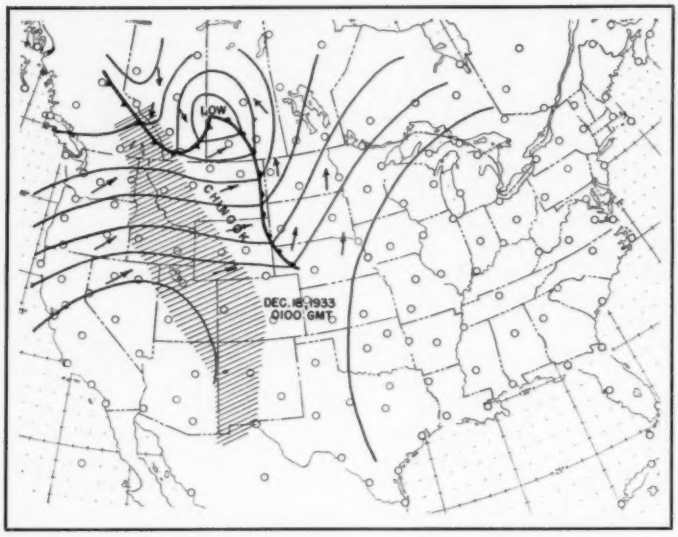


FIG. 5. Weather map during chinook conditions at Havre, Montana, at 0100 GMT, 18 December 1933.

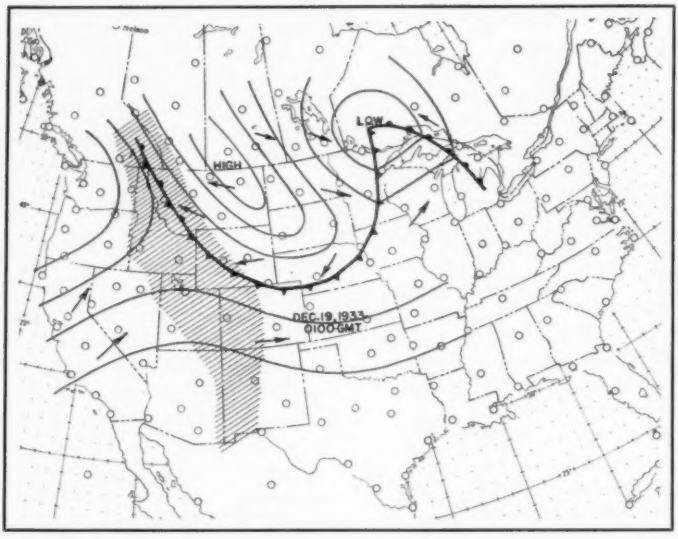


FIG. 6. Weather map twenty-four hours later than Fig. 5, showing Havre and northern Plains covered by a fresh, cold high pressure area at 0100 GMT, 19 December 1933.

over, representative of true chinook conditions, since the Black Hills case must be considered, more or less, a freak.

In mid-December 1933, a severe cold spell prevailed in Montana with temperatures registering as low as −13° F. At 1919 in the evening of the 19th, "almost like a shot from a cannon," the chinook hit, and under the influence of 25 to 30 mph southwest winds, the temperature jumped almost instantly from −9° to +18°, continuing upward more slowly for the next 24 hours, reaching +44° by the evening of the 17th. Next day another cold wave struck, with the temperature dropping close to zero accompanied by a northerly wind veering gradually into the east. On the 19th, the wind suddenly turned back to southwest, the temperature rapidly rose above freezing, and the snow began to melt. This continued about two hours until the wind again went

into the north and the cold air came back. That evening the chinook returned again, this time with the temperature rising to +50°, permitting rapid thawing. The warm period continued only 11 hours until a return to Arctic conditions the following morning. Additional thawing and freezing occurred alternately during the next few days as the chinook came and went. To a meteorologist, the explanation of this changeable sequence of events is obvious. A series of low pressure troughs moved out of the Pacific Coast area and then eastward across northern United States. As each disturbance moved across the Rockies, winds swung to southwesterly and chinook conditions prevailed (fig. 5). As the low moved east of the Rockies, the Havre area came under the influence of the northerly winds behind the low, which drew down another push of cold air behind an Arctic cold front (fig. 6). Another low in the series then moved inland and the sequence of events was repeated. The alternation of thawing and freezing occurring in this situation was unusual, since chinook conditions usually stay around for at least a few days once they become established.

## SOME PECULIARITIES

There are some interesting peculiarities of the chinook that are worthy of mention. One of these can best be described from the experience of the writer while residing at Great Falls, Montana. The city of Great Falls is located in the Missouri River valley bottom, while the municipal airport is elevated a few hundred feet above the valley floor. At times the valley floor will be immersed in cold Arctic air, while a chinook is blowing at places out of the valley such as the airport. Automobiles parked in the valley at night became very cold, and when driven up the hill into the warm chinook air, a heavy frost formed on the outside of the car as the moisture that had been picked up by the chinook from melting snow, condensed in contact with the cold car body. Vision through the windows was lost in a matter of seconds, to produce a severe driving hazard to one not prepared. The way to combat this danger is to operate defrosters well ahead of time in order to have the windshield as warm as possible so that it, at least, will remain clear. A similar danger faces those who drive from the warm air on the hill down into the cold valley. If the windows of the car are left closed, the sudden chilling from the outside will cause rapid fogging, or even frosting—this time on the inside of the car windows.

An interesting optical phenomenon called "looming" or "towering" is often noticed just preceding the chinook. Mountains located to the west of the viewer may appear to be stretched out to considerably greater than normal height due to optical effects produced by a very shallow layer of cold air surmounted by warmer air at higher elevations. Referring to figure 7, suppose that the viewer (at A) sees the lower part of the mountains through the cold air, while the line of sight to the upper part of the mountains goes out of the cold air and into the warm air. Light rays going from the optically less dense warm air to the optically more dense cold air will be refracted or bent downward, and light ray CBA from point C, which reaches the eye of

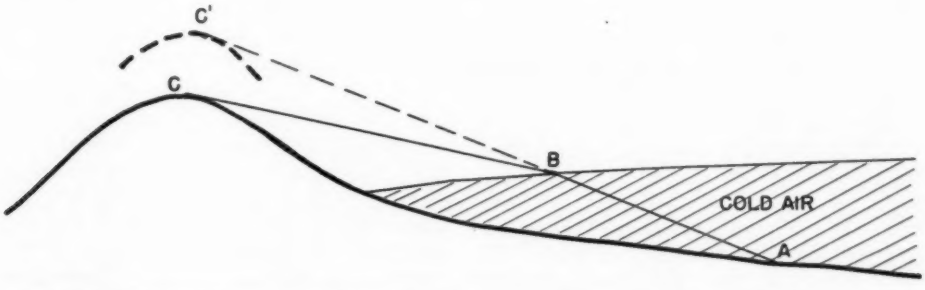


FIG. 7. Diagram showing distortion involving bending of light rays on passing from warm into cold air.

the viewer after being bent at B, will appear to come from point C′. Portions of the mountains viewed wholly through the cold air will appear normal, while those portions involving bent light rays will appear extended in a vertical direction. This makes the mountains appear higher, closer, and distorted, and is, of course, a form of mirage.

No discussion of the chinook would be complete without at least a mention of "foehn sickness." In Europe the foehn wind has been given the blame for a variety of ills which seem to accompany the onset of this famous wind (4). Very little has been written in English on this subject, and in general Americans in the chinook belt are unaware that the European counterpart of their chinook apparently does cause a considerable amount of physical discomfort. This illness seems to take a rather indefinite form, but it is generally associated with a feeling of low spirits, general ill-being, and depression—the suicide rate is said to be unusually high during periods when a foehn from the south is blowing. Other symptoms are reported to be muscular convulsions, heart palpitation, headaches, and increased heart disease. Europe has a variety of mountain ranges and therefore a variety of foehn winds. However, only the south foehn, which blows northward down the Alps out of Italy and into Switzerland, Austria, and Germany seems to produce this strange illness.

European scientists and doctors have attempted to explain foehn sickness in terms of various meteorological elements which may vary with the onset of this wind. Some rather elaborate studies have been made trying to test whether pressure pulsations (at lower than sound frequencies), temperature change, increased oxygen, decreased water vapor, or possibly the presence of some noxious gas such as nitrous oxide might account for foehn sickness. So far all of these approaches have given either negative or inconclusive results. Some of the more recent theories attempt to tie foehn sickness to variations in the electrical field of the atmosphere or to the concentration of positive ions. Whatever the cause, it seems to operate as effectively in carefully closed rooms as in exposed places.

We have seen the chinook as a welcome saviour from winter snow and cold, bringing warmth to the early settlers of the western plains and uncovering grass for the cattle to eat. We have also seen it as the subtle purveyor of strange maladies. Its story is but another of a long list of fascinating tales in the science of meteorology.

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2. Hamann, R. R. The Remarkable Temperature Fluctuations in the Black Hills Region. *Monthly Weather Review*, 71–1, January 1943, 29–32.
3. Math, Frank A. Battle of the Chinook at Havre, Montana. *Monthly Weather Review*, 62–2, February 1934, 54–56.
4. Berg, Hellmut. The Action of Foehn on Human Beings. *Geofisica Pura e Applicata*, 17–3&4, October–December 1950, 104–111. (In German with brief abstract in English.)


## Origin of the Term "Chinook"

The name "Chinook" is that of an Indian tribe which formerly lived near the mouth of the Columbia River. It was first applied to a warm southwest wind which blew from "over Chinook camp" to the trading post established by the Hudson Bay Company at Astoria, Oregon. The name soon came into general use in that locality, and as the adjacent country was settled the usage extended, so that now "Chinook" is applied not only to the warm, moist southwest winds along the Oregon and Washington coast, but to warm, dry, descending winds east of the Cascade range in Washington and the Rocky Mountains of Montana and elsewhere. ALVIN T. BURROWS, USWB, *Yearbook of the U. S. Dept. of Agriculture*, 1901, 555.

The Third Atmospheric Sciences Program—1961.

# Atmospheric Sciences Programs for High Ability Students

VINCENT J. SCHAEFER, *Atmospheric Sciences Research Center, State University of New York, Albany*

UNDER a blue sky streaked with jet stream clouds, the third annual summer Atmospheric Sciences Program for high ability secondary school students concluded its sessions on the Loomis School campus on 12 August 1961. Sponsored by the American Meteorological Society with support from the National Science Foundation, the 1961 final exercises featured a talk by Dr. Thomas Malone, president of the Society, the citation of six top students, and the granting of certificates to the 40 participants by Dr. Vincent J. Schaefer, director of the program since its inception in 1959.

## THE PHILOSOPHY OF THE PROGRAM

As in the previous summers, the curriculum was planned primarily to identify students having outstanding ability in the natural sciences, expose them to difficult but challenging intellectual experiences in order to arouse latent abilities, and thus motivate them to extend themselves beyond their previous academic efforts. Besides this attempt at activation, it was hoped that the students would be made better aware of the nature and methods of basic research so that by example and "doing" they would have a taste of various stimulating, intellectual activities four or five years before most students encounter them.

## THE IMPORTANCE OF THE ATMOSHERIC SCIENCES IN BASIC EDUCATION

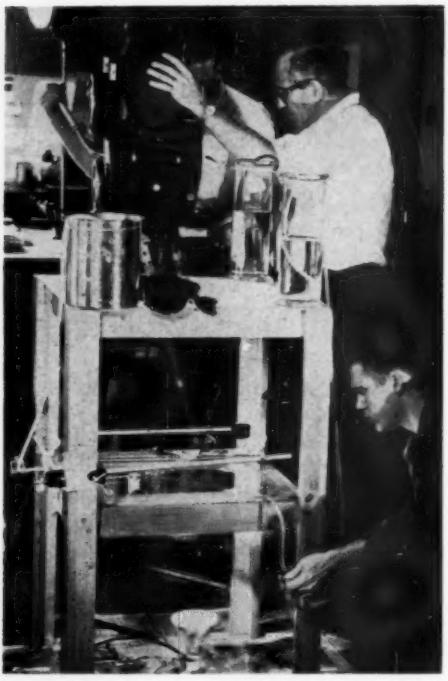
A program dealing with the atmospheric sciences is particularly well suited for illustrating the need of acquiring a broad education in basic sciences, since the person likely to make a major contribution to this field must be adept at handling interdisciplinary problems. The research problems offered at Loomis consisted of open-ended projects in such diverse areas as supercooling, crystallization, nucleation, replication, surface chemistry, electrification phenomena, fluid flow, polarization of light, aerosols, dynamic modeling, physical optics, and related atmospheric phenomena.

An important feature of the research activity placed the emphasis on simple equipment often made by the student, original design of experimental procedures, the development of techniques for determining the limits of a phenomenon, the organization of data, methods for testing ideas, and an awareness of the ever present possibility of encountering serendipitous events. The great value

of the research phase of the program was that these activities were not given by lecture alone, but each student had the personal experience of struggling with his individual problem, using his hands as well as his brains in furthering its development.

A seven-week period is a short time to reach the many objectives of the program, but it is remarkable how much can be accomplished if the students get off to a fast start and keep moving.

As an important part of the research program, every student had a project with a different objective. Although some parallelism occurred, this was all to the good since a considerable degree of cooperation develops among them. This intellectual interplay gives the student an awareness of the value of mutual help and the interchange of ideas. Excellent relationships developed among the participants and no obvious difficulties were detected throughout the summer.



CBS 20th Century on television location at Atmospheric Sciences Program filming Arthur Klieforth, Princeton '64, at work on his project: Bounce Effect on Water Drops and Electrical Properties.

## GEOGRAPHIC DISTRIBUTION OF STUDENTS AND THEIR ABILITY

The students taking part in the 1961 program came from 16 states and France. Their distribution was as follows: New York—8; Connecticut—7; Massachusetts—4; Illinois—4; Pennsylvania—3; California—2; Missouri—2; and one from: France, Louisiana, Maine, Michigan, Minnesota, Rhode Island, South Dakota, Vermont, Virginia, and Texas. Despite this wide geographic distribution of students and the different size of the schools attended, the variation in ability among the students as noted by the faculty seemed to depend primarily on the attitude of the individual student rather than on his geographic location or the excellence of his school.

As in the preceding two programs, six prizes in the form of recording barographs were presented through the courtesy of Science Associates Inc. The following students were cited:

TOP STUDENT IN ALL CATEGORIES (selected by Faculty)

Richard W. Hadsell
Mohonasen Jr.-Sr. High
Schenectady, New York

MOST POPULAR STUDENT (selected by Students)

Michael R. Potts
Oakland Technical High
Oakland, California

STUDENT SHOWING GREATEST IMPROVEMENT (selected by Faculty)

James W. Veilleaux
East Bridgewater High
East Bridgewater, Massachusetts

BEST STUDENT (by Grades)

John S. Lyons
Bethelehem Central Sr. High
Feura Bush, New York

STUDENT DOING BEST RESEARCH (by Evaluation)

Edmond W. Holroyd III
Spencerport Central High
Spencerport, New York

## STUDENT PRODUCING BEST PAPER

Alan S. Michelowski
New Britain Sr. High
New Britain, Connecticut

## ADVANCED PROGRAM OF JUNIOR RESEARCH FELLOWS

Although the Advanced Phase program, which proved to be so successful in 1960, was not again available for follow-up work with outstanding students, a special activity was included in the program with the cooperation of the Atmospheric Sciences Research Center (ASRC) of the State University of New York (SUNY).[1]

Five students, who were associated with the first Atmospheric Sciences Program in 1959 and who returned for the NSF supported Advanced Phase ASP of 1960, returned for the 1961 program. These students were granted Junior Fellowships by ASRC-SUNY. Board and room was also provided by SUNY with the cooperation of the Loomis School.

These young men, who had just completed their freshman year in college, continued work on the research projects they first started during the summer of 1959 or 1960. Their projects, which had assumed a considerable degree of sophistication, were carried out spontaneously and with a high degree of competence. In addition to conducting their own research work, they cooperated with the NSF program in various capacities: taking turns monitoring the library, assisting in the "met" lab, helping the new students with tricky techniques, leading discussion seminars, and making themselves useful in many other ways. Their example had a most salutary effect on the younger students and served to point out in a remarkable fashion the importance of early recognition of scientific ability.

## THE REACTION OF FORMER STUDENTS TO THE ATMOSPHERIC SCIENCES PROGRAM

A measure of the inherent value of any educational program is the impact it has on the participant when viewed in retrospect. A questionnaire was recently sent to the 75 students who participated in the 1959 and 1960 programs. To date replies have been received from 84 per cent of all students. Without a single exception all deemed the program worthwhile and about three-quarters wrote separate letters describing the manner in which it helped them individually.

More than 85 per cent of the students said they have retained an interest in meteorology and about the same percentage would like to continue research activities, especially if they can obtain summer jobs related to the atmospheric sciences.

Answers to a question relative to their activity during the summer of 1961 disclosed that considerably less than half of these high ability students were engaged in activities which could be interpreted as contributing to their intellectual advancement! Less than 15 per cent, including the five granted research fellowships by ASRC, were engaged in activities likely to nurture their interest in the atmospheric sciences.

## COLLEGES SELECTED BY HIGH ABILITY STUDENTS

In answer to a question relative to the colleges selected by these students, all of them were continuing their academic education. Answers to this question were also obtained from the 1961 students, since all except seven had definite ideas as to where they would seek admittance. (Since all of our students are in the category actively sought by colleges, often with very attractive scholarships as an inducement, these preferences indicate a likely acceptance by the institutes mentioned.)

More than 60 per cent of the students selected small colleges for their undergraduate studies, a total of 31 different institutions being cited. Of the 14 larger schools, M.I.T. and Harvard headed the list with 10 of the students actively participating and 11 expecting to attend. Of the smaller schools, R.P.I., Cal. Tech., Dartmouth, and Reed accounted for 12 students participating and four expecting to attend.

Since only one of the ten schools selected by these students offers courses in meteorology, and this one only at the graduate level, it is quite obvious that it is essential, if we are to succeed in retaining their present inter-

[1] Schaefer, Vincent J., Final Report on Atmospheric Sciences Program Sponsored by AMS and The Loomis School. S.P.I.S.E. Grant No. G-16, 714. August 15, 1961.

est in the atmospheric sciences, to provide an effective program of interesting, challenging, and worthwhile summer job opportunities. If proper attention is given to this type of activity, we may expect within the next few years an appreciable increase in the supply of outstanding young graduate students in the atmospheric sciences.

These young men will be among the leaders of the sciences during the next twenty years. Whether or not they will be actively involved in solving some of our problems in the atmospheric sciences will depend to a considerable degree on whether we provide suitable exposure to our problems and interesting projects during their undergraduate activities.

## FUTURE OF THE SECONDARY SCHOOL PROGRAMS

For several cogent reasons the 1961 summer program marks the end of the Loomis School series. I hope to help develop a similar program at the Desert Research Institute of the University of Nevada during the next few years. At the same time plans are developing for the establishment of an Advanced Phase program under the sponsorship of ASRC-SUNY. This is planned as a field research activity to be conducted in the Adirondack Mountains of northern New York, centered about Whiteface Mountain.

I also hope it will be feasible to develop further plans for undergraduate research programs in the form of field and laboratory studies centered about the multitude of interesting problems needing attention in the atmospheric sciences. Insofar as possible these programs will be planned to give each student the opportunity to assume a considerable degree of responsibility in carrying out the program. The projects will involve problems likely to extend him intellectually and to uncover weak points in his present knowledge so that they may be rectified at the period in his academic career when the acquisition of further knowledge is both feasible and practical to achieve.

It is to be hoped that the scientific community will become more actively concerned with the development of stimulating programs for high ability students. These are our most valuable natural and essentially undeveloped resources. Certainly there is no effort which produces more satisfying experiences than to be associated with such fine youngsters.

Junior Research Fellow, ASRC, Edson Blackman, Trinity '64, developing his project: Effect of Soluble Salts on Ice Crystallization.

# A Selective Bibliography in Meteorology

This popular book list was first prepared in 1958 by members of the AMS staff. It has now been revised and new titles added. Some out-of-print books have been included, due to their importance, since they may be found in many libraries. Juveniles have been omitted from the present bibliography. Addenda and new titles will be listed in *Weatherwise* periodically.

POPULAR: Abbe, Truman, *Professor Abbe and the Isobars: The Story of Cleveland Abbe, America's First Weatherman.* New York, Vantage Press, 1955. 259 p. $3.50. Biography of a man and his efforts to initiate daily weather predictions in 1869 and his attempts to make the Government weather conscious.

Battan, Louis J., *The Nature of Violent Storms.* Anchor Books, New York, Doubleday & Co., 1961. 158 p. 95¢. A discussion of the mechanism of extra-tropical cyclones, hurricanes, tornadoes, etc. and modern research toward understanding them.

Blumenstock, D. I., *Ocean of Air.* New Brunswick, N. J., Rutgers Univ. Press, 1959. 457 p. $6.75. A survey of the many aspects of modern meteorological knowledge and practice. The physical composition of the air, observing, forecasting, and controlling the weather are considered; also man and his biological and economic relationships with the air.

Bolton, J., *The Wind and the Weather. Past, Present and Future.* New York, Thomas Y. Crowell, 1957. 277 p. $3.95. Covers many subjects connected with post-war weather service: IGY, satellites, atomic explosions and the weather, hurricane reconnaissance, tornado research, military meteorology, etc.

Brooks, C. F., *Why the Weather.* Rev. ed. New York, Harcourt, Brace, 1935. $4.75. Descriptive. Excellent for high school students. Discusses actual weather conditions, normal and unusual, throughout U. S. by seasons.

Fisher, R. M., *How About the Weather?* New York, Harper, 1958. 2d ed. $3.75. A readable non-technical book which discusses the elementary physics of the atmosphere and shows how to forecast from newspaper weather maps and local signs.

Forrester, Frank H., *1001 Questions Answered about the Weather.* New York, Dodd Mead, 1957. 419 p. $6.00. Questions about the weather and how it is predicted for the layman and amateur. Good selective bibliography.

Hare, F. K., *The Restless Atmosphere.* New York, Rinehart, 1953. 192 p. $1.50. Text on synoptic climatology dealing with climates of America and Europe and the tropics; illustrations by weather maps for typical situations which prevail under different air mass movements. Out-of-print.

Inwards, R., *Weather Lore.* Edited by E. L. Hawke. London, Rider, 1950. 251 p. $2.10. By far the best collection of classic weather rules and adages culled from the world's literature.

Kimble, George H. T., *Our American Weather.* New York, McGraw-Hill, 1955. 322 p. $4.75. The typical weather of each month is discussed in individual chapters, along with the extremes which may occur. Entertaining and informative.

Krick, I. P., and R. Fleming, *Sun, Sea and Sky; Weather in Our World and in Our Lives*. Philadelphia, Lippincott, 1954. 248 p. $3.95. Practice of rainmaking emphasized. Also new developments in meteorology discussed.

Laird, Charles, and Ruth Laird, *Weathercasting. A Handbook of Amateur Meteorology*. Englewood Cliffs, N. J., Prentice-Hall, 1955. 163 p. $3.95. For amateur meteorologists. Explains principles of observing, forecasting, construction of weather instruments, etc.

Lehr, Paul E., R. Will Burnett, and Herbert S. Zim, *Weather: Air Masses, Clouds, Rainfall, Storms, Weather Maps, Climate*. New York, Simon and Schuster, 1957. (Golden Nature Guide.) 160 p. Cloth $1.95, paper $1.00. What makes the weather, how studied and forecast. Elementary guide to meteorological phenomena and processes with beautiful color illustrations.

Longstreth, T. M., *Understanding the Weather*. New York, Macmillan, 1953. 118 p. $2.50. This is a revision of his *Knowing the Weather* published in 1943. Aspects of meteorology and climatology discussed as well as amateur observing and forecasting.

Murchie, G., *Song of the Sky*. Cambridge, Mass., Houghton-Mifflin, 1954. 438 p. $5.00. Glorifies and romanticizes science and nature. Exciting and readable text covering many aspects of navigation and aeronautical meteorology.

Sloane, Eric, *Book of Storms*. New York, Duell, Sloane and Pearce, 1956. $3.50. By means of many charts and diagrams, Sloane explains the dynamics of cold and warm fronts, hurricanes, tornadoes, dust storms, thunderstorms, etc.

Sloane, Eric, *Eric Sloane's Almanac and Weather Forecaster*. New York, Duell, Sloane and Pearce, 1955. 169 p. $3.50. Week-by-week account of the weather as experienced by the author in rural New England.

Sloane, Eric, *Eric Sloane's Weather Book*. New York, Duell, Sloane and Pearce, 1952. $3.75. A coordinated collection of Eric Sloane's well-known weather illustrations and cartoons with appropriate text. Will be appreciated by all ages.

Sloane, Eric, *Look at the Sky*. N. Y., Duell, Sloane & Pearce, 1961. $3.75. Concerning the movement of a large air mass.

Spar, Jerome, *The Way of the Weather*. Mankato, Minn., Creative Educational Society, 1957. 224 p. $4.95. In cooperation with the American Museum of Natural History. For both elementary science and general science students. Reviews weather across U. S., weather for each season, weather forecasting instruments, etc. Excellent illustrations.

Spilhaus, A. F., *Weathercraft*. New York, Viking, 1951. 64 p. $2.00. A guide to building a back yard weather station with easily obtained material, along with an explanation of the weather map.

Stewart, G. R., *Storm*. New York, Modern Library (254), 1941. $1.65. The life history of a storm from mature typhoon to extra-tropical stage. Relates with dramatic impact its effect on California. Originally published by Random House, 1941.

Sutton, O. G., *The Challenge of the Atmosphere*. New York, Harper & Brothers, 1961. 227 p. $5.95. Meteorology is presented as an analytic and deductive science with fascinating challenges. Written in straight-forward, non-mathematical language for the American audience. By far the best survey of our science available in concise form.

Whelpley, Donald A., *Weather, Water and Boating*. Cambridge, Md., Cornell Maritime Press, 1961. 151 p. $4.00. Meteorology and oceanography for the small boat owner.

Yates, R. F., *Weather for a Hobby, a Guide to the Construction and Use of Weather Instruments Intended for Amateurs*. Rev. ed. New York, Dodd Mead, 1956. 181 p. $3.00. Excellent basic material with diagrams and charts for building a home observatory from readily available materials.

ELEMENTARY TEXTS: Best, A. C., *Physics in Meteorology*. New York, Pitman, 1957. 159 p. (Pitman's Applied Physics Series.) $3.75. Elementary. Meteorology covered in eight chapters. Weather forecaster takes part in a physical experiment in which the whole world is the laboratory.

Blair, Thomas A., and Robert C. Fite, *Weather Elements: A Text in Elementary Meteorology*. New York, Prentice-Hall, 1957. 414 p. $6.75. Textbook furnishing basic knowledge of weather elements for students and those who wish an understanding of the weather.

Boy Scouts of America, *Weather*. New York, Boy Scouts of America, 1952. Merit badge instruction booklet.

Day, John A., and Fred W. Decker, *Rudiments of Weather*. Corvallis, Oregon, O.S.C. Cooperative Assoc., 1955. $3.50. Story of our energetic atmosphere. Text suitable for student who has not necessarily studied college physics and mathematics. "Quiz yourself" pages.

Donn, W. L., *Meteorology—With Marine Applications*. (2d ed.) New York, McGraw-Hill, 1951. 465 p. $6.25. General introduction to meteorology for marine deck officers. Observational and theoretical aspects of basic weather elements considered.

Great Britain—Meteorological Office, *Meteorology for Mariners, with a Section on Oceanography*. London, Her Majesty's Stationery Office, 1956. 274 p. $2.80. Good textbook for students or seamen. Marine aspects of meteorology, climatology, and forecasting.

Halpine, C. G., and H. H. Taylor, *Mariner's Meteorology*. Princeton, Van Nostrand, 1956. 371 p. $8.00 (text ed. $6.00). A textbook for naval officers and others interested in marine aspects of atmospheric behavior with special emphasis on forecasting and observing the sea.

Hess, S. L., *Introduction to Theoretical Meteorology*. New York, Holt, 1959. 362 p. $8.50. A textbook for the undergraduate meteorology student.

Neuberger, H., and F. B. Stephens, *Weather and Man*. New York, Prentice-Hall, 1948. 272 p. $3.75. An introductory text section is followed by a description of how weather affects man in his private and business life. Elementary text suitable for college survey or home study.

Neuberger, H., *Introduction to Physical Meteorology*. University Park, Pa., Penna. State University, 1951. 271 p. $3.50. Provides a basic understanding of physical principles where most American texts are weak.

Panofsky, Hans, *Introduction to Dynamic Meteorology*. Univ. Park, Penna. State University, 1956. 243 p. $4.00. Primarily for forecasters who would like to review dynamic meteorology with special emphasis on the physical basis of numerical forecasting. Also suitable for college students on the junior and senior level.

Petterssen, S., *Introduction to Meteorology*. New York, McGraw-Hill, 1958. 2d ed. 327 p. A complete revision of the well-known college text of 1941. Emphasis is on physical principles, but without requiring advanced mathematics.

Taylor, G. F., *Elementary Meteorology*. New York, Prentice-Hall, 1954. 364 p. $5.95. Up-to-date textbook in general meteorology for the undergraduate degree candidate.

ADVANCED TEXTS: Brooks, C. E. P., and Carruthers, N., *Handbook of Statistical Methods in Meteorology*. London, Her Majesty's Stationery Office, 1953. 412 p. (Air Ministry Met. Office 538). $3.50. Thorough treatment of application of statistics to climatological or meteorological problems.

Byers, H. R., *General Meteorology*. 3rd ed. New York, McGraw-Hill, 1959. 540 p. $9.50. This well-known text for mature students has been almost completely rewritten with emphasis on the fundamental physics of the atmosphere.

Godske, C. L., T. Bergeron, J. Bjerknes, and R. C. Bundgaard, *Dynamic Meterology and Weather Forecasting*. Boston, American Meteorological Society, 1957. 800 p. $15.00. Book divided into five parts: (1) Thermodynamics and statics of the atmosphere, (2) kinematics of the atmosphere, (3) hydrodynamics of the atmosphere, (4) climatological and synoptic models, (5) weather forecasting.

Haltiner, George J., and Frank L. Martin, *Dynamical and Physical Meteorology*. New York, McGraw-Hill, 1957. 470 p. $10.50. Well-organized and simple text for meteorology majors and practicing forecasters primarily interested in large-scale atmospheric motions.

Humphreys, W. J., *Physics of the Air*. (3d ed.) New York, McGraw-Hill, 1940. Out-of-print. A revision of an earlier work which contains much practical material not found in one volume elsewhere.

Johnson, John C., *Physical Meteorology*. New York, Wiley, 1954. 393 p. $7.50. Detailed treatment of dynamic and physical meteorology: ionospheric physics, cloud physics and "rain-making," radar meteorology, icing of aircraft, and meteorological optics.

Panofsky, Hans, and Glenn W. Brier, *Some Applications of Statistics to Meteorology*. University Park, Pa., Penna. State University, 1958. 224 p. Aims at serving as textbook for meteorology students and to acquaint active forecasters and research personnel with modern statistical techniques.

Petterssen, S., *Weather Analysis and Forecasting*. 2d ed. New York, McGraw-Hill, 1956. 2 v. v. 1. Motion and motion systems. 446 p. $9.50. v. 2. Weather and weather systems. 284 p. $6.50. A revision and expansion of an earlier work which brings thinking on this subject up-to-publication-date.

Riehl, Herbert, *Tropical Meteorology*. New York, McGraw-Hill, 1954. 392 p. $9.25. Systematic treatment of weather, climatic, synoptic, and dynamic meteorology of tropical and subtropical regions. Well-illustrated.

Saucier, W. J., *Principles of Meteorological Analysis*. Chicago, University of Chicago, 1955. 438 p. $10.00. Detailed text on meteorological analysis discussing its theory and methods of presentation.

Sutton, O. G., *Atmospheric Turbulence*. 2d ed. New York, Wiley, 1955. 111 p. $1.75. Pocket size text; deals with turbulence in general, the meteorology of the lower atmosphere, early theories, diffusion, eddies, and applications.

Sutton, O. G., *Micrometeorology: A Study of Physical Processes in the Lowest Layers of the Earth's Atmosphere*. New York, McGraw-Hill, 1953. 333 p. $9.00. Treats problems of turbulence, diffusion, evaporation, and local heating in the few feet above the ground where we and the plants and animals live.

Thompson, Philip D., *Numerical Weather Analyses and Prediction*. N. Y., The Macmillan Co., 1961. 170 p. $6.50. Stresses fundamental physical and mathematical aspects; designed for student at graduate level and for "outside contributor" to meteorology.

Willett, H. C., and F. Sanders, *Descriptive Meteorology*. 2d ed. New York, Academic Press, 1959. 355 p. $7.50. Intended for students with a knowledge of calculus and college physics.

SPECIAL SUBJECTS:

Battan, Louis J., *Radar Meteorology*. Chicago, Univ. Chicago Press, 1959. 161 p. $6.00. A general introduction which considers the theoretical background and the practical applications for the "non-radar meteorologist."

Bell, Corydon, *Wonder of Snow*. New York, Hill and Wang, 1957. $5.00. All about snow, from crystal to snowstorm to glacier. Lively and informative.

Bolin, Bert, ed., *The Atmosphere and the Sea in Motion*. New York, Rockefeller Institute Press and Oxford Univ. Press, 1959. 509 p. $15.00. A memorial volume to Prof. Carl-Gustaf Rossby consisting of 46 papers by eminent authors who were associated with the brilliant career of the late former president of the AMS.

Byers, H. R., ed., *Thunderstorm Electricity*. Chicago, University of Chicago Press, 1953. $7.00. Consists of 16 contributions by experts doing research in atmospheric electricity.

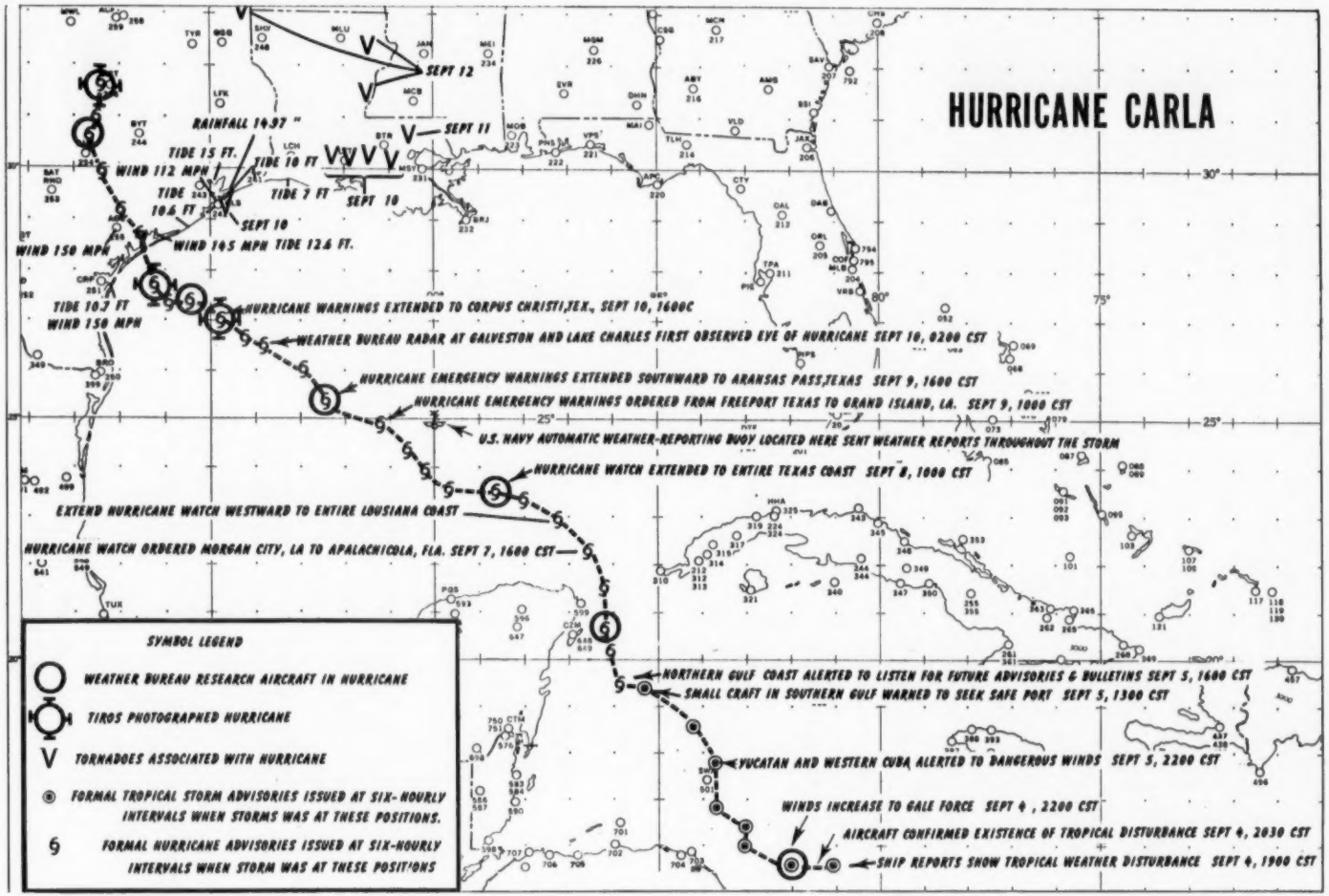
Chalmers, J. A., *Atmospheric Electricity*. New York, Pergamon, 1957. $10.00. 327 p. Summary of up-to-date thinking about phenomena connected with atmospheric electricity.

Douglas, M. S., *Hurricane*. New York, Rinehart, 1958. 393 p. $5.95. A popular account of the main West Indian and North American hurricanes, mainly historical and not strictly meteorological.

Dunn, G. E., and B. I. Miller, *Atlantic Hurricanes*. Baton Rouge, La., Louisiana State Univ. Press, 1960. 326 p. $10.00. A thorough, up-to-date study of the hurricane phenomena which has superseded Tannehill's standard book. Will appeal to both professional and layman alike.

Flora, S. D., *Hailstorms of the United States*. Norman, Okla., University of Oklahoma Press, 1956. $3.50. Treats the formation of hailstones, the oddities of hail and hail damage, forecasting, and insurance against. Tabulates hail damage by states and describes the most destructive hailstorms.

*(Continued on page 199)*


HURRICANE CARLA
SEPT 12
SEPT 11
SEPT 10
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TIDE 15 FT.
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TIDE 10 FT
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TIDE 7 FT
WIND 150 MPH
WIND 145 MPH TIDE 12.6 FT.
TIDE 10.7 FT
WIND 150 MPH
HURRICANE WARNINGS EXTENDED TO CORPUS CHRISTI,TEX., SEPT 10, 1600C
WEATHER BUREAU RADAR AT GALVESTON AND LAKE CHARLES FIRST OBSERVED EYE OF HURRICANE SEPT 10, 0200 CST
HURRICANE EMERGENCY WARNINGS EXTENDED SOUTHWARD TO ARANSAS PASS,TEXAS SEPT 9, 1600 CST
HURRICANE EMERGENCY WARNINGS ORDERED FROM FREEPORT TEXAS TO GRAND ISLAND, LA. SEPT 9, 1000 CST
U.S. NAVY AUTOMATIC WEATHER-REPORTING BUOY LOCATED HERE SENT WEATHER REPORTS THROUGHOUT THE STORM
HURRICANE WATCH EXTENDED TO ENTIRE TEXAS COAST SEPT 8, 1000 CST
EXTEND HURRICANE WATCH WESTWARD TO ENTIRE LOUSIANA COAST
HURRICANE WATCH ORDERED MORGAN CITY, LA TO APALACHICOLA, FLA. SEPT 7, 1600 CST
NORTHERN GULF COAST ALERTED TO LISTEN FOR FUTURE ADVISORIES & BULLETINS SEPT 5, 1600 CST
SMALL CRAFT IN SOUTHERN GULF WARNED TO SEEK SAFE PORT SEPT 5, 1300 CST
YUCATAN AND WESTERN CUBA ALERTED TO DANGEROUS WINDS SEPT 5, 2200 CST
WINDS INCREASE TO GALE FORCE SEPT 4 , 2200 CST
AIRCRAFT CONFIRMED EXISTENCE OF TROPICAL DISTURBANCE SEPT 4, 2030 CST
SHIP REPORTS SHOW TROPICAL WEATHER DISTURBANCE SEPT 4, 1900 CST
SYMBOL LEGEND
WEATHER BUREAU RESEARCH AIRCRAFT IN HURRICANE
TIROS PHOTOGRAPHED HURRICANE
TORNADOES ASSOCIATED WITH HURRICANE
FORMAL TROPICAL STORM ADVISORIES ISSUED AT SIX-HOURLY INTERVALS WHEN STORMS WAS AT THESE POSITIONS.
FORMAL HURRICANE ADVISORIES ISSUED AT SIX-HOURLY INTERVALS WHEN STORM WAS AT THESE POSITIONS

# Hurricane CARLA

THE New Orleans Weather Bureau issued Hurricane Emergency Warning Advisory, Number 20, at 1000 CST, Saturday, 9 September 1961:

Hoist Hurricane Warnings 10 AM Freeport Texas to Grand Isle Louisiana and gale warnings elsewhere from Corpus Christi Texas to Pensacola Florida. Hurricane large and dangerous is moving between west northwest at about 9 mph and present indications are that it will turn to a more northerly course with the center moving inland on the northern Texas coast or extreme western Louisiana Sunday. Winds and tides will gradually increase in areas of display reaching gale force over much of the area by tonight and hurricane force winds should begin over much of the hurricane display area by early Sunday. Tides will rise reaching 5 to 10 feet in areas of display Sunday and tides will reach 10 to 15 feet above normal in an area near and 100 miles to east of where center crosses the coast. All persons should evacuate all islands and low coastal areas on the Louisiana and upper Texas coast immediately. Preparations against these dangerous conditions winds and tides should be started immediately and completed tonight to insure safety of the persons, animals and property. Every precautionary measure possible should be taken since this is a very dangerous hurricane and the large size of the hurricane will result in a long duration of hurricane conditions with very strong winds and extremely dangerous flooding. Small craft Brownsville Texas to St. Marks Florida should remain in safe shelter.

At 10 AM CST . . . 1600Z Hurricane CARLA was centered near latitude 24.9 and Longitude 91.3 or about 380 miles southeast of Galveston Texas. Highest winds are estimated 135 mph near the center and hurricane force winds extend outward about 100 miles to north and 50 miles to the south. Gales extend outward 300 miles to north and east of the center and 200 miles to the south. The lowest pressure in the center this morning was 28.17 inches. Vessels in the path of this dangerous hurricane should exercise extreme caution.

All interests along the northern and western Gulf especially on the Louisiana and Texas coasts should keep posted on the latest advisories and bulletins on CARLA.

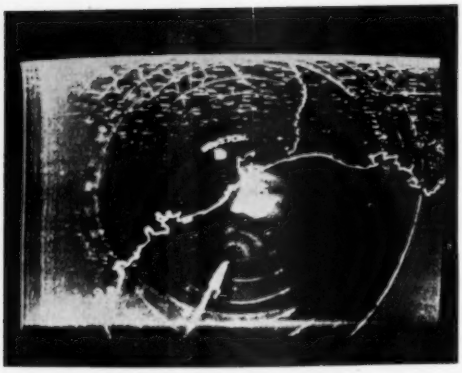
The advisory issued at 1000 on Saturday morning, the 9th, initiated the largest mass movement of people from a storm area ever known, and probably constituted the largest evacuation of a threatened area to occur in peacetime. An estimated 500,000 persons sought safety on high ground away from the coast.

CARLA continued to move toward the central Texas coast at a forward speed of 9 mph. As the center approached the coast on the 10th, winds reported at 150 mph whirled around the center whose barometric pressure was close to 27.50"/931.2mb. The forward movement of this giant tropical intruder slowed late on the 10th to about 6 mph as the center, according to triangular radar fixes, pursued an erratic course and performed a complete loop. This unforeseen hesitation delayed CARLA'S arrival on the shoreline and brought the center onshore farther south than earlier anticipated.

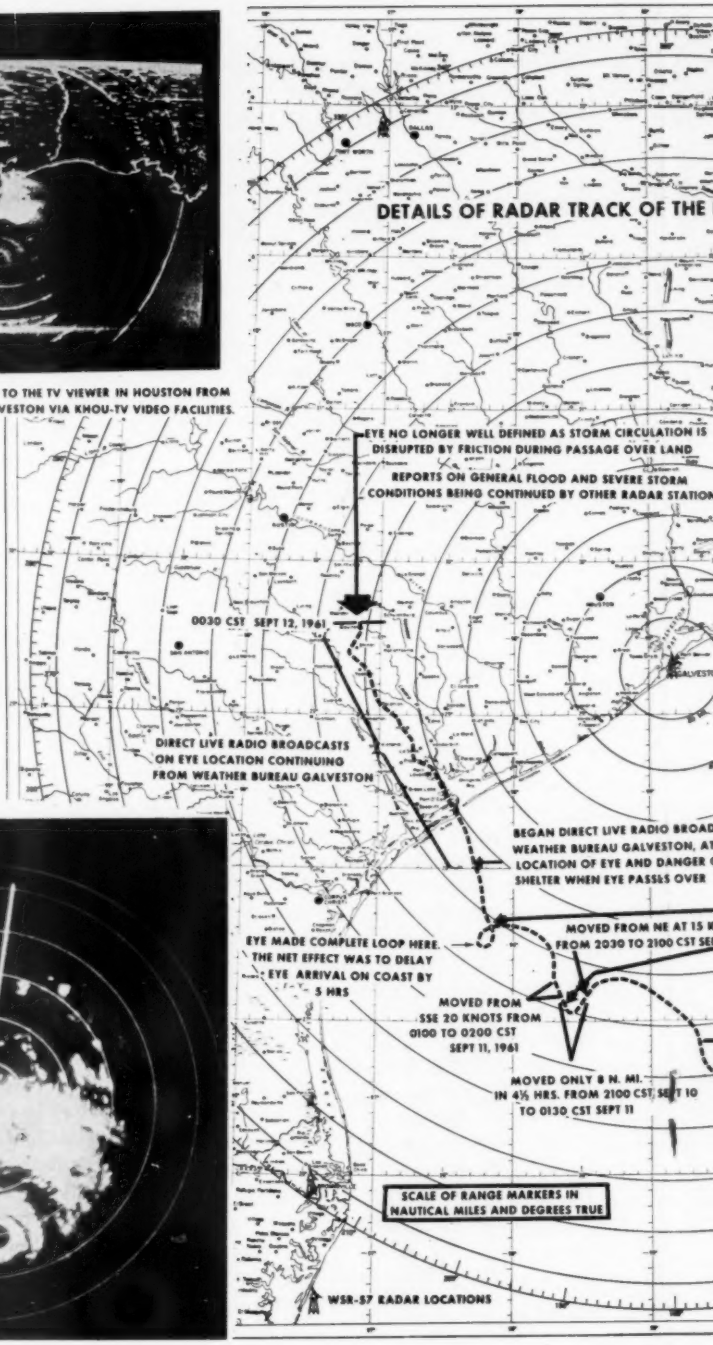
CARLA moved inland near the Port O'Conner-Port Lavaca area (near Cavallo Pass at the northern end of Matagorda Island) on Monday afternoon, 11 September. In advance of the eye many stations along the coast reported their highest winds that morning. The leading edge of the eye reached Port Lavaca between 1500 and 1600 CST. The storm followed a northwesterly course carrying the center near Inez, Yoakum, Waelder, Austin, Waco, Fort Worth, and Dallas.

Gusts of hurricane force were reported from Galveston to Corpus Christi, a distance of approximately 200 miles. A peak gust of 170 mph was estimated at Port Lavaca. Gusts of 150 mph were estimated at Victoria, Port Aransas, and Edna. Sustained winds (fastest mile) were reported as 115 at Matagorda, 110 at Victoria, and 88 at Galveston.

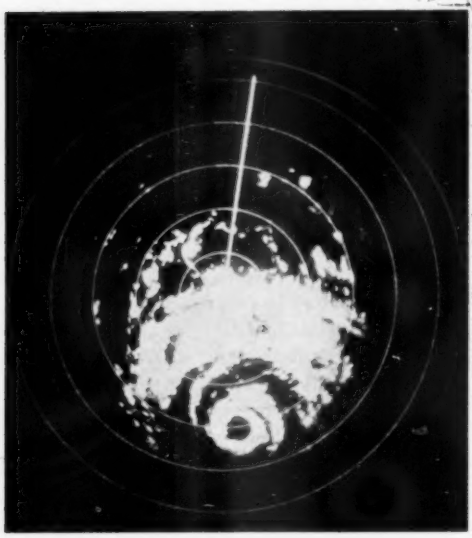
Tides of 10 feet and over above mean sea level were estimated along the coast from

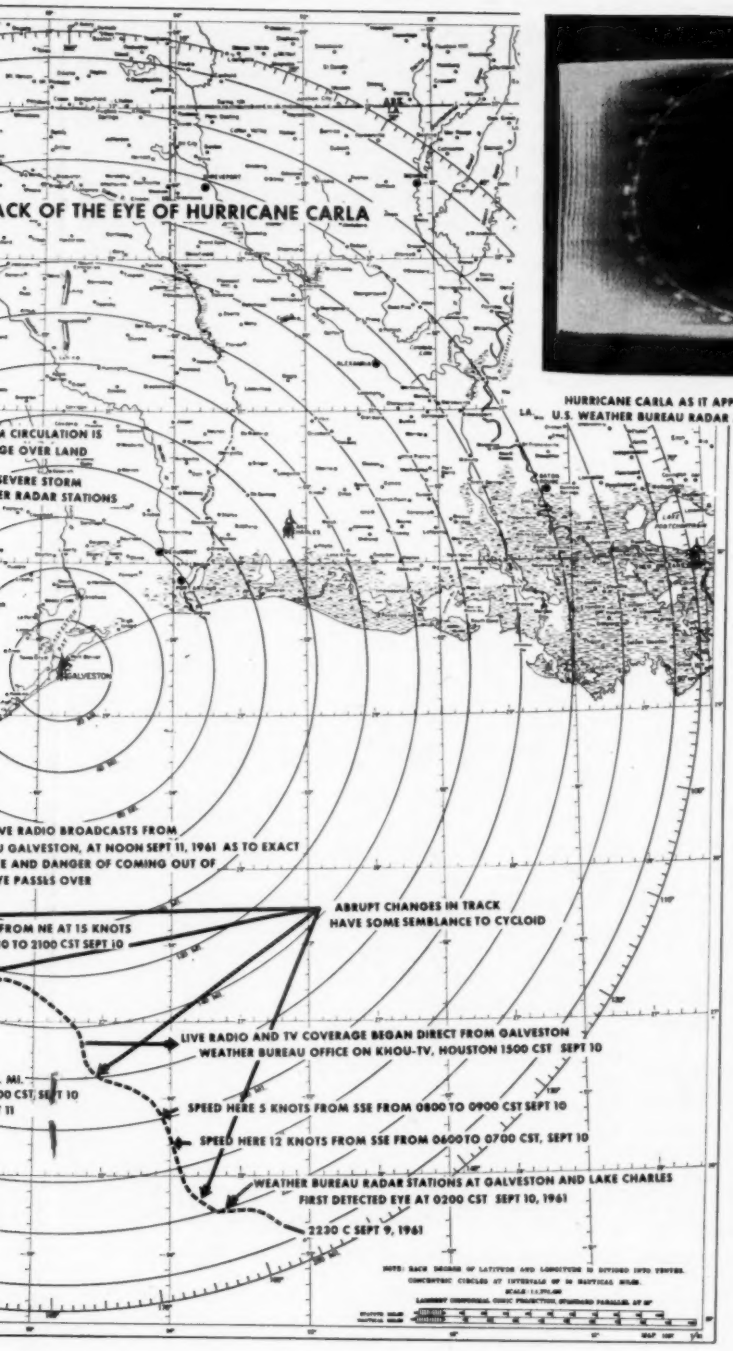


HURRICANE CARLA AS IT APPEARED TO THE TV VIEWER IN HOUSTON FROM U.S. WEATHER BUREAU RADAR AT GALVESTON VIA KHOU-TV VIDEO FACILITIES.


DETAILS OF RADAR TRACK OF THE
EYE NO LONGER WELL DEFINED AS STORM CIRCULATION IS DISRUPTED BY FRICTION DURING PASSAGE OVER LAND
REPORTS ON GENERAL FLOOD AND SEVERE STORM CONDITIONS BEING CONTINUED BY OTHER RADAR STATION
0030 CST SEPT 12, 1961
DIRECT LIVE RADIO BROADCASTS ON EYE LOCATION CONTINUING FROM WEATHER BUREAU GALVESTON
BEGAN DIRECT LIVE RADIO BROAD
WEATHER BUREAU GALVESTON, A
LOCATION OF EYE AND DANGER
SHELTER WHEN EYE PASSES OVER
MOVED FROM NE AT 15 K
FROM 2030 TO 2100 CST SE
EYE MADE COMPLETE LOOP HERE. THE NET EFFECT WAS TO DELAY EYE ARRIVAL ON COAST BY 5 HRS
MOVED FROM SSE 20 KNOTS FROM 0100 TO 0200 CST SEPT 11, 1961
MOVED ONLY 8 N. MI. IN 4½ HRS. FROM 2100 CST SEPT 10 TO 0130 CST SEPT 11
SCALE OF RANGE MARKERS IN NAUTICAL MILES AND DEGREES TRUE
WSR-57 RADAR LOCATIONS

Hurricane CARLA, eye bearing 150 nautical miles 170° from Galveston 10 September 1961. USWB photo from WSR-57 radar.

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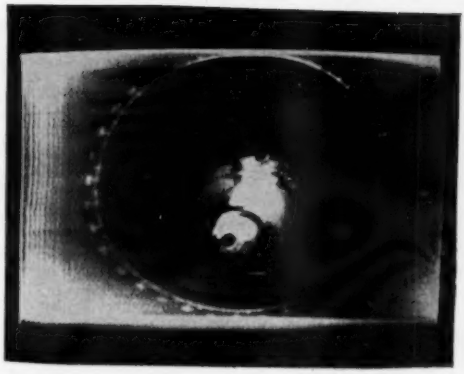
GALVESTON, AT NOON SEPT 11, 1961 AS TO EXACT
E AND DANGER OF COMING OUT OF
E PASSES OVER
FROM NE AT 15 KNOTS
0 TO 2100 CST SEPT 10
ABRUPT CHANGES IN TRACK
HAVE SOME SEMBLANCE TO CYCLOID
LIVE RADIO AND TV COVERAGE BEGAN DIRECT FROM GALVESTON
WEATHER BUREAU OFFICE ON KHOU-TV, HOUSTON 1500 CST SEPT 10
SPEED HERE 5 KNOTS FROM SSE FROM 0800 TO 0900 CST SEPT 10
SPEED HERE 12 KNOTS FROM SSE FROM 0600 TO 0700 CST, SEPT 10
WEATHER BUREAU RADAR STATIONS AT GALVESTON AND LAKE CHARLES
FIRST DETECTED EYE AT 0200 CST SEPT 10, 1961
2230 C SEPT 9, 1961



HURRICANE CARLA AS IT APPEARED TO THE TV VIEWER IN HOUSTON FROM U.S. WEATHER BUREAU RADAR AT GALVESTON VIA KHOU-TV VIDEO FACILITIES.

Courtesy USWB.

Port Aransas to Sabine Pass. The highest tide reported was 18.5 ft at Port Lavaca. Matagorda reported 12.6 ft, Port Aransas 10.9 ft, Freeport 10.8 ft, Texas City 10.1 ft, and Sabine Pass 10.0 ft. Port Arthur reported a highest tide of record, 7.8 ft.

A low pressure of 27.62″/935.3mb was reported by the Bauer Dredging Company at Port Lavaca from a recently calibrated barometer at 1610 CST before the needle went below the scale. Other low pressures were 27.92″/945.5mb at Victoria and 28.60″/968.5 mb. Austin and Fort Worth experienced their lowest pressures of record: 28.73″/972.9 mb and 28.94″/980mb, respectively.

Torrential rains of 10 to 16.5 inches accompanied hurricane CARLA 50 miles inland. Rainfall amounts decreased progressively northward in Texas with 4 to 5 inches over the northeastern section. Some of the heaviest storm totals were Galveston Airport 16.49 inches, Galveston City Office 14.94 inches, Wharton 13.05 inches, Liberty 12.55 inches, Dickinson 12.47 inches, and Flatonia over 11.8 inches.

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Even though her center crossed the Texas coastline some 120 miles to the southwest, CARLA struck a severe blow at the city of Galveston with sustained hurricane force winds, excessive tides, torrential downpours, and death-dealing tornadoes. Records indicate that since the turn of the century only the hurricanes on 8 September 1900 (The Galveston Disaster) and on 17 August 1915 were more destructive on Galveston Island. In the Nineteenth Century the storms on 4–5 October 1837 and 3 October 1867 rate in the above category. CARLA, thus, takes a place among the five severest hurricanes in the Galveston area in recorded meteorological history.

The first influences of CARLA'S extensive circulation were felt about 2000, 6 September, when light east and northeast winds sprang up. During the next two days the east and northeast air flow gradually increased in speed; on the 9th the steady northeasterlies were clocked at an average of 20.4 mph. On the 10th, as the storm center approached from the southeast, the northeast winds increased to gale force before veering to the east about 2100, for a day's average of 39.3 mph.

A shift of wind to southeast about 0900 on Monday morning, the 11th, indicated that the center would pass inland south of the city. The gales had already produced hurricane force gusts up to 112 mph before the recorder became inoperative shortly after 1300. The fastest sustained mile of wind on the regular recorder came at 1418 with 90 mph from the southeast. Estimated gusts of 120 mph occurred during the afternoon of the 11th during the peak of the storm. The average for the entire 24 hours was 51.1 mph.

The lowest barometer in Galveston read 29.24″/990.2mb at 1715 on the 11th when the storm center was just inland, northeast of Victoria, some 125 miles to the west-southwest.

CARLA spawned two tornadoes which passed over Galveston before dawn on the 12th and resulted in five deaths and many injuries. The major twister cut through the central part of the city destroying many houses and damaging the Court House which was being used as a storm shelter. At least four other tornadoes were associated with CARLA in Texas and seven in Louisiana.

Tides along the Gulf shore and in Galveston Bay commenced rising within 24 hours of CARLA'S entrance into the Gulf of Mexico on the 7th. A peak tide of 8.8 ft was reached at 1520 on the 11th. There was extensive flooding on Galveston Island and along the shores of the bay where water marks indicated tides from 10 to 15 feet above normal.

As CARLA moved northward through eastern Texas on the 12th, the winds at Galveston continued to veer and decreased in speed to an average flow of 33.5 mph for the 24 hours, still a respectable figure. By evening of the 13th CARLA had lost its tropical characteristics and moved into Oklahoma. Thus, Galveston had been under the hurricane's influence for seven full days.

(Data supplied by Ernest Carson, USWB, Galveston, Texas, and by Arthur I. Cooperman and Howard C. Sumner, Marine Section, Office of Climatology, USWB, Washington.)

# Spacecraft Views DEBBIE

Hurricane DEBBIE in central North Atlantic as it was photographed from the Mercury Spacecraft orbiting the earth. The photo was taken at 0916 EST, 13 Sept. 1961, twelve minutes after launching of the Mercury-Atlas 4 Spacecraft from Cape Canaveral, Florida. The storm center lies 100 miles north of the projected flight line. The Spacecraft traveled at 17,519 mph at a maximum altitude of 158.6 miles. NASA photo.

# ESTHER — A "First" Lady

HURRICANE ESTHER, aside from keeping the Atlantic seaboard on the alert for a fortnight in September, achieved a notable place in meteorological history under at least three scores:

(1) TIROS III made an historic "first" by locating a suspicious cloud area on 10 September near 11°N, 30°W. The existence of a circulation was confirmed next day by the TIROS photo below and from ship reports. An aircraft dispatched to the scene on the 12th reported ESTHER had developed hurricane force winds.

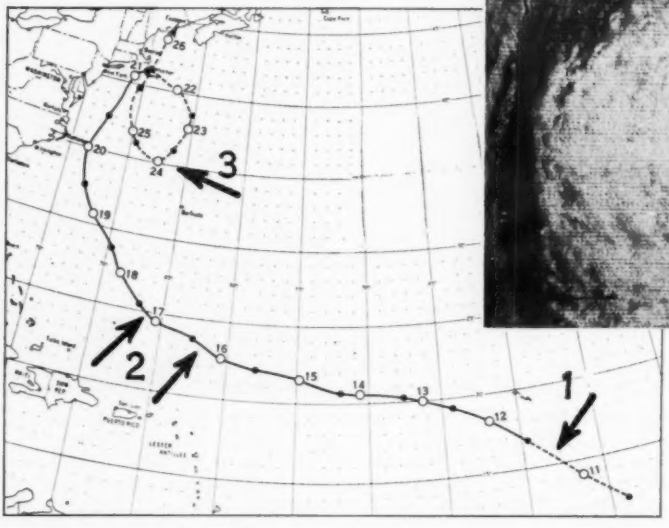
(2) ESTHER was the "first" hurricane to have a fully-documented seeding operation when Navy, Air Force, and Weather Bureau planes injected silver iodide into the cloud structure and observed the results with both longwave and shortwave radar.

At 1500 EST on the 16th and again at 1100 on the 17th, silver iodide was injected downward into the cloud tops of ESTHER near the point of maximum winds, 10 to 15 miles north of the storm center, where temperature were near −60°C., down to the freezing level—a layer six miles thick.

The conversion of liquid water to ice crystals was observed by aircraft radar flying at 7,000, 10,000, 20,000, and 40,000 feet. Within half an hour most of the seeded sector had disappeared from the longwave (water droplet detecting) radar, but was still clearly visible on the shortwave (ice crystal detecting) radar and to the human eye. Apart from the temporary conversion of supercooled water to ice, no changes which can be attributed to the seeding operation were observed in the storm.

(3) ESTHER was probably the "first" hurricane to make a threatening stab at the New England coast and return four days later, after making a complete loop southerly to the latitude of Cape Hatteras, to again skirt Cape Cod and move into Maine. Blocking to the north and east prevented ESTHER from pursuing a normal course. A somewhat similar circumstance occurred on 30 September 1894 when a vigorous hurricane also lost energy in the Block Island-Cape Cod area, but map data is insufficient to determine whether the storm performed an offshore loop.

Hurricane ESTHER
11–26 September 1961



The first initial identification of a hurricane circulation by a satellite. Hurricane ESTHER as viewed by TIROS III at 1335 EST, 11 September 1961, near 15°N, 38°W. NASA-USWB photo.

(*Continued from 191*)

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George, J. J., *Weather Forecasting for Aeronautics.* New York, Academic Press, 1960. 673 p. $15.00. One of America's most experienced forecasters has brought together his many contributions in a single, well-coordinated volume.

Hoyt, W. G., and W. B. Langbein, *Floods.* Princeton, Princeton University Press, 1955. 469 p. $7.50. Authoritative and readable book on flood history, flood hydrology, and flood control.

Ludlam, F. H., and R. S. Scorer. *Cloud Study—A Pictorial Guide.* Prepared under the auspices of the Royal Meteorological Society. New York, Macmillan, 1957. 80 p. $2.95.

Mason, Basil John, *The Physics of Clouds.* New York, Oxford University, 1957. 481 p. (Oxford Monographs on meteorology.) $11.20.

Nakaya, Ukichiro, *Snow Crystals—Natural and Artificial.* Cambridge, Harvard University Press, 1954. 510 p. $10.00. On atmospheric conditions responsible for the wide variations in crystal formation assumed by snow crystals. Of interest to both professional and amateur meteorologists. Well illustrated with 514 figures and 40 tables.

Rue, E. Aubert de la, *Man and the Winds.* New York, Philosophical Library, 1955. 224 p. $6.00. A survey of winds all over the world showing how man has used or protected himself from or adapted his habitation to them. Popular.

Tannehill, I. R., *Drought, Its Causes and Effects.* Princeton, Princeton University Press, 1947. 246 p. $3.75. Drought and accompanying phenomena described. Cycles, climate change, and weather control considered.

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Whitnah, D. R., *A History of the United States Weather Bureau.* Urbana, Univ. of Illinois Press, 1961. 267 p. $6.00. The story of the founding of the meteorological service of the Signal Corps, its transformation into the Weather Bureau, and the latter's expansion of activities and services in observing, forecasting, and research in the modern day.

World Meteorological Organization, *International Cloud Atlas-Album.* Geneva, Switzerland, The World Meteorological Organization, 1956. $0.95. Consists of 32 plates: 19 in black and white, 13 in color. Especially intended for pilots and airborne observers.

World Meteorological Organization, *International Cloud Atlas—Abridged Atlas.* Geneva, Switzerland, The WMO, 1956. $1.85. Contains representative selection of 72 plates from vol. 2: 42 in black and white and 30 in color, together with a brief descriptive and explanatory text to meet day-by-day needs of meteorological observers at surface stations.

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OBSERVING: Great Britain—Meteorological Office. *Handbook of Meteorological Instruments.* London, Her Majesty's Stationery Office, 1956. 458 p. $6.30. Detailed information about construction, installation, correcting, recording, and maintenance.

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Kraght, P., *Meteorology Workbook with Problems*. Cambridge, Md., Cornell Maritime Press, 1943. $2.50. Practical problems, quizzes, and map drawing exercises.

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Aronin, Jeffrey E., *Climate and Architecture; progressive architecture book*. New York, Reinhold, 1953. 302 p. $12.50. Discusses various types of climate-adapted architecture. How the weather elements influence building design and community planning.

Baver, Leonard D., *Soil Physics*. New York, John Wiley, 1956. 489 p. $7.75. Meteorological factors affecting soil structure, moisture, productivity, and erosion.

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Franklin, T. B., *Climates in Miniature: A Study of Micro-climate and Environment*. New York, Philosophical Library, 1955. 137 p. $3.75. Popularized study of weather effects on gardens and fields by a devoted nature lover.

Geiger, Rudolf, *The Climate Near the Ground*. Cambridge, Mass., Harvard University Press, 1957. 494 p. $6.00. Revised edition. A comprehensive survey of micrometeorological problems. Valuable both for the researcher and the general reader. Includes revised bibliography.

Haurwitz, Bernhard, and James M. Austin, *Climatology*. New York, McGraw-Hill, 1944. 410 p. $8.50. A college text. Approach is from the dynamical climatology viewpoint with much emphasis on air masses and moving disturbances.

Huntington, Ellsworth, *Civilization and Climate*. New Haven, Yale University Press, 1933. 333 p. $5.50. A study of climate factors in the rise and decline of various civilizations.

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Markham, S., *Climate and the Energy of Nations*. London, Oxford, 1944. 236 p. $3.50. Out-of-print. Traces historic movement of civilization centers. Three last chapters deal with America.

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Thomas, Morley K., *Climatological Atlas of Canada*. Ottawa, National Research Council, 1953. 253 p. 84 maps. $2.00. Data on average distribution and extremes of temperature, humidity, wind, snowfall, rainfall, and sunshine. Of special value to designers and building engineers.

Trewartha, Glenn T., *Introduction to Weather and Climate*. New York, McGraw-Hill, 1954. 402 p. $7.75. A text which emphasizes both the systematic aspects of the subject and the regional features as revealed in world weather patterns.

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Visher, S. S., *Climatic Atlas of the United States*. Cambridge, Mass., Harvard University Press, 1954. 403 p. $9.00. A series of 1,031 maps of rather small format which depict the distribution of the weather elements by month, season, and year.

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*Journal of Applied Meteorology*. Quarterly. AMS, 45 Beacon St., Boston 8, Mass. $12.00 to non-members.

*Journal of the Atmospheric Sciences*. Bimonthly. AMS, 45 Beacon St., Boston 8, Mass. $15.00 to non-members.

*Journal of Geophysical Research*. Monthly. Amer. Geophys. Union, 1515 Mass. Ave., N.W., Wash., D. C. $20.00 to non-members.

*The Mariner's Weather Log*. Bimonthly. U. S. Weather Bureau. Superintendent of Documents, Gov't Printing Office, Wash. 25, D. C. $1.00.

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*Monthly Weather Review*. Monthly. U. S. Weather Bureau. Superintendent of Documents, Gov't Printing Office, Wash. 25, D. C. $3.00.

*Transactions of the American Geophysical Union*. Bimonthly. National Research Council, Amer. Geophys. Union, 1515 Massachusetts Ave., Washington 25, D. C. $9.00.

*Weatherwise*. Bimonthly. AMS, 45 Beacon St., Boston 8, Mass. $4.00.

GREAT BRITAIN

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*Meteorological Magazine*. Monthly. British Met. Office. Her Majesty's Stationery Office. $4.50.

*Quarterly Journal of the Royal Meteorological Society*. RMS, 49 Cromwell Road, London S.W. 4, England. $19.60.

*Weather*. Monthly. RMS, 49 Cromwell Road, London S.W. 4, England. $3.35.

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*Australian Meteorological Magazine*. Canberra. Quarterly.

*Bulletin of the World Meteorological Organization*. Quarterly. WMO, Geneva, Switzerland. $1.00.

*Geophysical Magazine*. Irregular. Central Met. Observatory. Tokyo, Japan.

*Indian Journal of Meteorology and Geophysics*. Quarterly. Indian Met. Dept. Manager of Publications, Delhi, India.

*Notos*. South African Weather Bureau. Pretoria. Quarterly. $4.90.

*Tellus: a quarterly journal in geophysics*. Swedish Geophysical Society. Lindhagensgatan 124, Stockholm. $7.85 with postage.

U. S. WEATHER BUREAU (Climatological)

*Average monthly weather resume and outlook*. Semi-monthly. Presents in graphic form the observed temperature and precipitation departures from normal for the past month and experimental monthly outlook covering expected temperature and precipitation. Cat. No. C30.46. $5.00 per year.

*Climatological Data for the United States by sections*. Monthly with annual summaries. Contains weather statistics from 47 separate sections. (Indicate desired section when ordering.) One section $2.50 per year. All sections $48.00 per year. Cat. No. C30.18.

*Climatological Data. National Summary*. Monthly. Contains condensed data for 1st order stations. $4.00 per year with annual summary. Cat. No. 30.51.

*Daily Weather Map*. Daily weather map, Washington forecasts, and occasional feature articles. $9.60 per year. Cat. No. C30.12.

*Local Climatological Data*. Monthly. Daily and monthly observational data for each of about 270 stations. Specify city desired. Price per city $1.50 per year. Cat. No. C30.56.

*Monthly Climatic Data for the World*. Monthly. Contains surface pressure, temperature, humidity, precipitation as well as upper-air temperature and dew point for selected world cities. $2.75 per year. Cat. No. C30.50.

*Storm Data*. Monthly. Contains storm data and unusual weather phenomena; tabulated by states as to time, path, damage, casualty and brief description. $1.50. ($2.00 foreign).

*Weekly Weather and Crop Bulletin*...National Summary. Synopsis of weekly climate conditions and their effects on crops and farming. Also contains snow, ice and degree day data in winter. $3.00 per year. Cat. No. C30.11.

U. S. GOVERNMENT PUBLICATIONS

*Aneroid Barometer*. How to read and set a barometer. (1957). 10 p. 15¢. Cat. No. 330.2:B26/2.

*Aviation Series*. Set of pamphlets: 1-18 inclusive. Aimed at helping pilots to apply weather knowledge to practical flight problems. (1957). Complete set 75¢. Cat. No. C30.65:1-18.

*Climates of the States*. Series of 51 pamphlets containing narrative description of climates and weather, temperature, and precipitation tables. Prices vary from 10¢ to 25¢.

*Cloud Code Chart*. 36 illustrations of cloud forms, including nomenclature and codes. 31 × 14 in. Cat. No. 30.22:C 62/2/958. 10¢.

*Hurricane Warnings*. 4-page leaflet describing hurricanes, warnings, precautions. Cat. No. C30.2:H 93/3/958. 5¢.

*Hurricane Tracking Chart*. Hurricane area shown with text on warnings and precautions. 19 × 24 in. Cat. No. C30:22:H 94/959. 10¢.

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*Instructions for Climatological Observers*. 10th ed. Methods of taking rainfall, temperature, etc. observations, and descriptions of instruments. (1955). 55¢. Cat. No. C30.4:B/955.

*Lightning*. Causes and effects of lightning, safety precautions, and geographical distribution of thunderstorms. Cat. No. 30:2:L 62. 4 p. 5¢.

*Manual of cloud forms and codes for states of the sky*. Definitions and descriptions of the forms of clouds with 47 illustrations. (1956). 30¢. Cat. No. C30.4:S/956.

*Manual of marine meteorological observations*. Instructions for taking observations at sea. (1954). $1.25. Cat. No. C30.4:M/956 1 & 2.

*Manual of surface observations*. Instructions for taking and encoding observations for transmission. New edition being prepared.

*Pilot's weather handbook*. Basic information to enable a pilot to profit by weather forecasts. FAA. (1955). $1.50. Cat. No. C31.138:104.

*Practical methods of weather analysis and prognoses*. Discusses the generally accepted methods of forecasting from current map data. Naval Weather Service. (1955). $2.00. Cat. No. D202.6:v37.

*Preparation and Use of Weather Maps at Sea*. Circular R. A guide for mariners. 4th ed. 1959. $1.25.

*Principal tracks and mean frequencies of cyclones and anticyclones in the Northern Hemisphere*. Detailed history of cyclone and anticyclone track charts, etc. by William Klein. (1956). $1.00. Cat. No. C30.29:40.

*It Looks Like a Tornado*. An aid in distinguishing tornadoes from other cloud forms. 11 p. Cat. No. 30.6/2:T 63. 10¢.

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(Write to Publications, U. S. Weather Bureau, Washington 25, D.C., for *Selected List for Weather Science Study* and *An Annotated Meteorological Bibliography for Secondary Schools* (10¢). Also to Superintendent of Documents, Washington 25, D.C. for *Price List 48, Weather, Astronomy, and Meteorology*.

Data by Office of Climatology, USWB.

# A Record Summer: Hot West, Cool Midwest & South

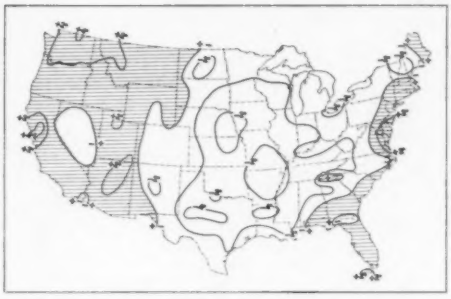
DAVID M. LUDLUM

**JULY**—The mean surface weather maps for July exhibited very small deviations from normal pressure readings over the U. S. and southern Canada. A trough of low pressure in the central part of the continent, stretching from Quebec southwestward to Texas, provided the principal feature of most weather maps, especially during the middle period from the 10th to the 25th, and it largely determined the temperature and precipitation regimes of the month.

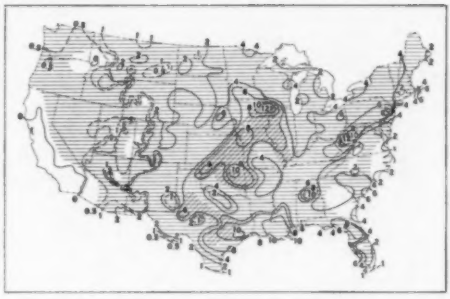
Temperatures in the trough ran persistently below normal as is evinced at St. Louis, Missouri, in the heart of the Mississippi Valley, where every day from the 1st through the 26th averaged below normal. Practically all of the area in the United States between the Rockies and the Appalachians had either *below* or *much below* temperature averages as a northwesterly flow of polar air persisted and daytime convective cloudiness reduced the effect of solar radiation. Minus departures from normal, however, were not as extreme as this area experienced in the very cool month of June.

The precipitation pattern also reflected the influence of the main central trough—a long band of *heavy* rainfall extended northeastward in the moist current of southwesterlies from Texas to Quebec. Rainfall also proved very adequate in the central part of the trough where clashing air masses produced heavy moisture in another band from southern Texas northward to Iowa and Illinois.

**CIRCULATION**—Ridge conditions dominated the weather of the Pacific Coast and Plains states northward into western Canada. Upper-air circulation charts showed pressure considerably above normal from about 150°W in the eastern Pacific Ocean off British Columbia east-northeastward across central Canada to the Hudson Bay area. The ridge conditions over western Canada displaced the usual monsoon low pressure region, usually found over central Canada, to a point in Quebec farther east than normal, thus opening all of central United States to the inflow of polar air from northerly regions. The slope of the streamlines from northwest to southeast was particularly steep over the U. S. Rockies and Plains with the result that many places in Texas and the interior of the Gulf region experienced their coolest July of record.



Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.



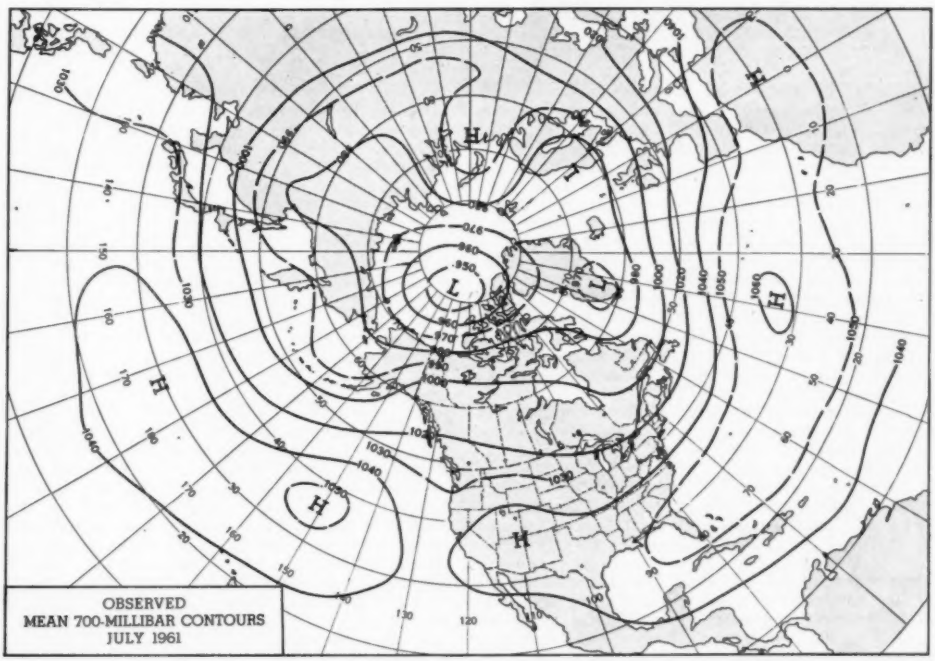
Total Precipitation in inches. USWB chart.

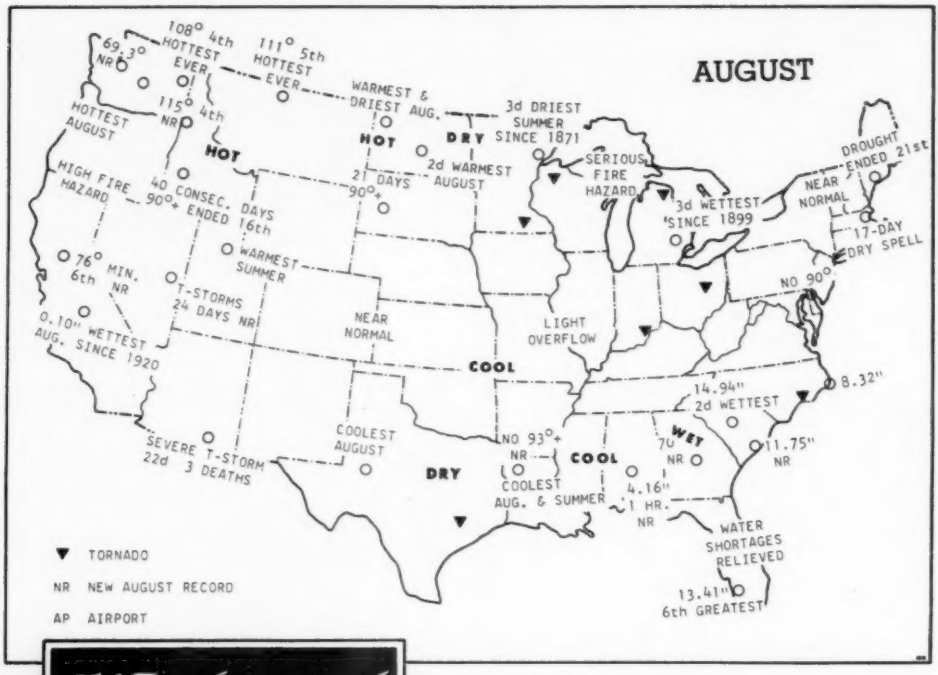
In the ridge west of the Rockies conditions generally repeated the thermal pattern of the previous month, though the degree of excessive heat was much less than in the searing June of 1961, a month that set many all-time records for extremity and persistency of early summer heat. At Sacramento, the heat wave, described as "one of the longest and warmest periods in 85 years of record," commenced on 13 June and continued until 28 July when the circulation abruptly changed. Likewise, east of the central trough, ridge conditions prevailed along the Atlantic seaboard as the Bermuda High gradually developed into a major pressure feature: from the 17th to the end of the month every day but two at New York City averaged above normal—from the 21st to the 26th there were six consecutive 90° days. The extension inland of the Bermuda High kept the Southeastern coastal strip both warm and dry throughout the month.

The circulation regime across the continent in July may be divided into three time periods. For the

(*Continued on page 210*)

The upper-air map below shows the pattern of air flow for July at about 10,000 feet, on which the average weather largely depends. The contours lines represent the mean height of the 700 mb. pressure level. Figures are in tens of feet: 1020 = 10,200 ft., 980 = 9,800 ft., etc. Chart by Extended Forecast Section, USWB.






# Weatherwatch

Data by Office of Climatology, USWB.

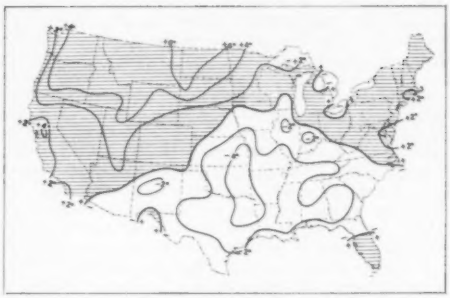
**SUMMER 1961**—In a rather remarkable persistence of temperature trends, August continued the general regime of the previous two summer months: a very warm West, a very cool Midwest and South, and a sometimes warm, sometimes cool Atlantic seaboard. The three-month continuance of similar thermal divisions across the breadth of the country produced some record conditions—eastern Montana and continguous areas had the warmest summer since the commencement of records in the 1870s, while northern Louisiana and central Mississippi experienced the coolest summer in the same span of records. Both June and August created new marks for departure from normal, both plus and minus, over widespread areas; July, though exhibiting the same general temperature trends, proved much less extreme than its companion months.

In the realm of precipitation, the summer season proved noteworthy in three respects: (1) a severe drought over the northwestern Plains caused the driest summer ever along the North Dakota-Montana border; most of Montana and much of Wyoming, North Dakota, and South Dakota received less than 50% of normal August rainfall; (2) adequate and well-spaced precipitation throughout the Corn Belt of the central and southern Plains and in all the Midwest produced a fruitful growing season; (3) heavy downpours in east Texas and along immediate Gulf locations eastward, as well as at separated points in the Appalachians, caused cloudbursts and flash flood conditions.

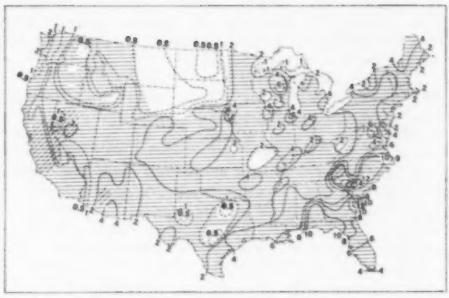
**AUGUST**—The main weather news of August was made in the first week when a heat wave in the Northwest reached its zenith on the 3rd, 4th, and 5th. The following excessive readings were registered: Idaho: Lewiston, 115°; Washington: Walla Walla, 113°; Oregon: Pendleton, 113°; and Montana: Havre, 111°. These preliminary state highs from first-order stations will probably be exceeded when the figures from cooperative stations have been tabulated. The August drought on the northwestern Plains concluded the most distressing growing season in many years in the great wheat growing areas on both sides of the international border. Williston, in northwestern North Dakota close to the border, illustrated conditions in this season of dearth—only 0.14″ of rain fell there in both the driest and hottest August in 83 years of records.

The climax of an extremely cool summer in the interior Gulf States was highlighted by the Shreveport, Louisiana, observations where every day in August averaged below normal, the month showed a 5.2-degree thermal deficit, and the mercury failed to top 93°—all new August records. Farther west, at Abilene in central Texas, the summer season's peak of 98° was the lowest summer maximum ever registered and only the second time since 1890 that the mercury failed to top 100°.

The only general storm of unusual meteorological interest within the United States during the month was noteworthy, not for its severity, but for its point of origin in the Florida Gulf area and for its north-



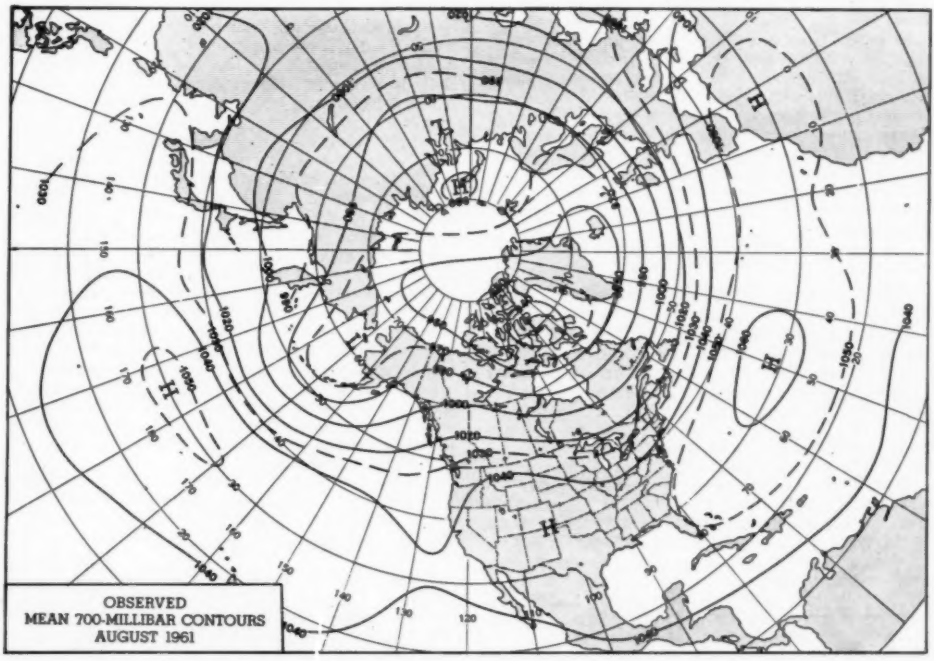
Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.



Total Precipitation in inches. USWB chart.

ward track parallel to and a short distance inland from the seaboard as it sped from Carolina to New England. This tropical depression, which never developed sufficient wind force to be classified as a tropical storm, formed in the southern end of a major north-south trough on the 18th, moved across northern Florida to reach a point off Savannah early on the 20th, was over Chesapeake Bay 24 hours later, and crossed into Canada from Vermont and New Hampshire on the forenoon of the 22nd. Rather heavy and widespread precipitation accompanied its passage northward: Jacksonville 4.90″, Augusta 3.59″, Raleigh 1.90″, Philadelphia 1.45″, Hartford 1.44″, and Caribou 1.05″.

**CIRCULATION**—Though at first glance the mean pressure maps for August seem to resemble those of July in location of troughs and ridges and in orientation of isobars, there were major basic differences. Whereas July had exhibited a degree of blocking with higher than normal pressure across central Canada, that area in August was the scene of great cyclonic activity with at least three depressions deepening to barometric readings close to 29.00″/982mb. The main polar vortex in August was centered over Baffin Land and northern Hudson Bay instead of over the North Pole as in July. Pressure, accordingly, averaged well below normal in central and northern Canada, but well above normal in the United States, an alignment producing a fast westerly



flow across the middle latitudes of the continent. The geographic location of ridges and troughs, though, was much the same as in July and produced similar temperature trends.

The main pressure feature of the first few days of August centered in a large upper-air ridge which migrated northward from the desert Southwest to a position over Idaho where it produced three extremely hot days on the 3rd, 4th, and 5th. The position of the center of the anticyclone aloft, lying well inland from the coast, permitted a southerly air flow from a dry, warm source over California and Nevada. The air subsiding under ridge conditions kept skies clear and allowed maximum solar radiation to raise temperatures to record August highs in some areas and in others to all-time highs. On the 5–6th the ridge center commenced to retreat southward to Arizona as a cold front, sweeping in from the Pacific Ocean, brought cooling air masses and dropped maxima by more than 20 degrees.

The southwestern anticyclonic conditions again built northward—by the 12th the center returned to Idaho and Montana. Though temperatures approached or reached 100° once more, they did not match the earlier extremities since the air flow into the ridge was mainly from a westerly quadrant, from the Pacific Ocean, rather than from a southerly direction off the continent.

The next major shift of atmospheric contours carried the western ridge eastward all the way to the upper Mississippi Valley and western Lakes region on the 17th. This created a mid-continent blocking situation of brief duration as the index of westerly flow dropped below the month's normal for the only time during the entire month of August.

The concluding twelve days of the month featured a great north-south trough, reaching from the sub-Arctic to the Gulf of Mexico, which showed remarkable tenacity in holding position and maintaining strength. Its primary center moved about—first over Baffin Land and Hudson Bay and later southward over Ontario and Quebec. During most of the period from the 18th to the 31st, a secondary closed low circulation aloft could be detected in the southern end of the trough either over the Gulf States or Texas. It was here that the tropical disturbance of the 18th was spawned and here that the cyclonic circulation aloft caused cloudy skies, abundant precipitation, and very cool temperatures to make the summer season of 1961 a memorable one in the Gulf States region.

## U. S. BRIEFS

Disastrous floods in eastern Puerto Rico on 26–27th sent streams to highest levels of record causing damage in millions . . . second greatest 24-hr. rainfall in August since 1871 at Charleston, S. C., when 6.33″ fell on 4–5th . . . " a very wet and gloomy month" at Greenville, S. C. . . . Charleston, W. Va., scene of floods in July, had third driest August with only 1.19″ . . . Boston's dry spell from 4th through 20th equaled the record dry duration for August . . . rain on 21st broke drought at Portland, Me., where only .03″ had fallen in 26 days . . . waterspouts observed along shore near Erie, Pa., on afternoon of 6th . . . a low reading of 39° at Sault Saint Marie, Mich., on 14th broke date record by five degrees . . . summer at Duluth with only 4.51″ was driest since 1936 and third driest of record . . . only one summer (1933) drier at Devil's Lake, N. D., and August warmest ever . . . hottest and driest August at Williston, N. D., since records commenced in 1878 . . . Ft. Worth's .02″ comprised the driest August since 1943 when only a trace was recorded . . . Baton Rouge, La., had coolest August since records began in 1893 . . . at Shreveport, La., every day averaged below normal and max. of 93° was lowest ever for an August . . . 98° at Abilene, Texas, was lowest summer max. ever . . . hottest August in airport history at Salt Lake City; record high minimum of 74° on 20th . . . over Nevada numerous showers following long drought caused widespread flooding and damage . . . 24 days with thunderstorms at Ely, Nevada, was greatest for any month of record . . . Fresno's .10″ on 5th was heaviest August rain since 1920 . . . August total of .39″ at Yuma was greater than had fallen in previous seven months of 1961 at the Arizona location . . . Boise, Idaho, had 40 consecutive days with 90° readings ending on 15th . . . hottest summer since records began in 1886 at Walla Walla, Wash., and max. of 112.6° on 4th was only 0.2° less than all-time max. set in 1898 . . . dry thunderstorms led to numerous forest fires in Oregon and northern California . . . Yakima, Wash., had highest August max. of record with 108.2° on 4th; caused scalding of fruit . . . Spokane's 108° on 4th equaled all-time high and set new mark for August . . . at Missoula, Mont., the previous highest for August of 102° was equaled or exceeded on 2nd, 3rd, 4th, and 5th.

## CANADIAN BRIEFS

August was another hot, dry, sunny month both in the Canadian West and in the Maritime provinces . . . in the agricultural areas of Alberta, Saskatchewan and Manitoba the summer of 1961 will be remembered as one of the hottest, driest and sunniest on record . . . as a result of the long dry spell in Newfoundland, catastrophic forest fires went out of control in the central and southeastern parts of the province; the loss to natural resources cannot now be estimated, but will be very great . . . forest fires were also disastrous in central British Columbia . . . most of western Canada reported temperatures more than five degrees above normal . . . Maple Creek, Saskatchewan, with 110° was the highest in the nation for the summer . . . Edmonton, Regina and Winnipeg all reported the warmest August in climatic history . . . it was also one of the driest Augusts on record in southern Saskatchewan and Manitoba . . . Regina had only .07″, almost all of which fell in a five-minute period . . . precipitation was generally above normal in southern Ontario and Quebec . . . it was the wettest August in 19 years at Montreal, as 5.41″ of rain fell . . . fine vacation weather in the Maritime provinces with little precipitation and warm sunny days . . . Sydney, N. S., with .70″ experienced the driest August of record . . . there was below normal rainfall throughout Newfoundland; at both Gander and St. John it was the driest on record . . . a minimum of +14° at Isachsen was the coldest in Canada during the month . . . five inches of snow were reported from Clyde . . . Isachsen and Mould Bay were the only stations to observe snow on the ground on 31 August.

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## July (*Continued from page 207*)

first ten days the upper-air Pacific ridge dominated air movement. It moved farther inland as the month opened to take a position as far east as New Mexico and Oklahoma by the 3–4th and expanded its influence over the southern Rockies and southern Plains

on the 6–7th. The ending of this phase was signaled on the 8–9th as the ridge retrogressed to southern California in conjunction with the development of a trough over the Plains and Prairies in the lee of the Rocky Mountains.

A closed low circulation aloft appeared over the Plains on the 13th and drifted eastward to reach Ontario by the 16th, its passage bringing beneficial rains to much of northern U. S. and southern Canada. In the trough's wake, an arm of the Pacific High again extended eastward as far as Arkansas and Louisiana on the 17th, but soon receded westward as another closed low circulation aloft appeared over Saskatchewan on the 18th. This feature drifted slowly southeastward, remained stationary over the Dakotas on the 21–22nd, then moved eastward on the 23rd to join a trough over Quebec. The eastward movement of this low was attended by widespread heavy precipitation and local severe storms in the Lake region, the Northeastern States, and adjacent Canada.

The remaining week of the month did not show any clear-cut circulation features. A rather flat westerly flow prevailed across the middle continent with a sprawling front, separating modified polar air on the north from tropical air to the south, fluctuating north and south over the Midwest, Ohio Valley, and Middle Atlantic States, with small waves moving eastward causing heavy downpours over small sections. Not until the final days of the month did tropical air penetrate very far northward into the Mississippi Valley. St. Louis had its first above normal day of the month on the 27th, and at Chicago's Midway Airport the first 90° reading of the month was not registered until the 30th.

## U. S. BRIEFS

Driest July of record (1.22″) at West Palm Beach, Fla., followed very dry June . . . at Apalachicola the month was .50″ drier than any previous July . . . fourteen consecutive days (13–26th) with 90° readings comprised longest sustained hot spell at Norfolk, Virginia, since records began in 1871 . . . at Boston cool first 17 days were balanced by warm concluding 14 days, departure from normal only 0.1° . . . small tornado at Buffalo on 7th picked up and injured a woman hospital employe; damage $10,000 to city . . . 43° on 9th was all-time July low at Cleveland Airport . . . wettest July at Charleston, West Virginia, with 13.54″; 2.92″ in one hour on 19th caused severe flash flood resulting in 21 deaths . . . tornadoes near Dayton, Ohio, on 28th caused $300,000 damage . . . low reading of 37° on 8th at Duluth Airport set new July all-time minimum record . . . a 24-hour downpour of 6.28″ on 1st at Dubuque, Iowa, was greatest such of record . . . coolest July (since 1872) at Shreveport, La.; 92° maximum was lowest July max. of record . . . coolest since 1908 at Abilene, Tex.; first time mercury did not exceed 95° in a July . . . for 44 consecutive days commencing 14 June temperature failed to exceed normal at St. Louis . . . Grand Junction, Colo., with 0.03″ had second driest July, and driest June-July of record . . . Salt Lake City had only one day with max. below 90° . . . Reno, Nevada, reservoirs at their lowest level since 1934; partial rationing of domestic and irrigation water in effect . . . Sacramento had a minimum of only 71° on 19th, highest daily minimum ever recorded there . . . a total of 35 days in June-July at Red Bluff, Cal., had 100°; eight had 110°, a new record.

## CANADIAN BRIEFS

Fine summer weather prevailed over British Columbia; new temperature records were established as readings in the 90's were recorded along the usually moderate Pacific coast . . . storms were very infrequent although a disturbance passing over the south coast on 5 July brought nearly a month's supply of precipitation on one day . . . national high temperature reported during the month was 103° at Ashcroft and Kamloops . . . the hot dry weather of June continued during most of the first half of July across the Prairie provinces . . . the drought was broken in most of southern Alberta and southern Manitoba but continued in southeastern Alberta and western Saskatchewan where July precipitation was less than half of normal . . . temperatures on the prairies were nearly normal in July and in Alberta and Saskatchewan June was the warmest month of the summer . . . in the past 75 years (at Edmonton and Calgary) this has only occurred twice before . . . the countryside was unusually green throughout July in southern Ontario and Quebec as a result of the cool weather and frequent showers . . . Montreal radar picked up showers within 140 miles of the city on 28 days of the month . . . La Cave on the Ontario-Quebec border reported 8.78″ of rain, a national high for July 1961 . . . generally fine dry weather prevailed over the four Atlantic provinces . . . in Newfoundland at Gander it was the driest July in 25 years as several serious forest fires continued to burn throughout the month . . . in contrast Goose, Labrador, reported 6.73 inches of rain, making it the wettest July ever . . . Halifax reported 17 days with fog as persistent fog conditions prevailed in the Atlantic and Bay of Fundy regions . . . although rainfall was below normal there was a very high incidence of thunderstorms in the Atlantic provinces . . . Chesterfield reported a minimum of +24°—the coldest in the country for the month . . . Fort Smith also in N.W.T. reported a maximum temperature of 92° . . . Holman Island reported 8″ of snow during the month but there was no measurable snow on the ground on 31 July at any regular Canadian weather reporting station.

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# Getting Colder!

The earth, with a few regional exceptions, is undergoing "a persistent cold wave" that began in the 1940's, according to J. Murray Mitchell, a USWB climatologist. His figures show a drop in mean temperature of one-half degree Fahrenheit over the last 20 years. The trend is most pronounced in the tropical area, with the United States, Western Europe, and the Pacific Coast of Asia as exceptions. Mr. Mitchell's studies were presented recently to the UNESCO-WMO symposium on climate change in Rome.

Mr. Mitchell did not predict that the warm period of almost a century's duration was over, but stated that the present cooling trend was "more persistent than any cooling trend in recorded data." The symposium is studying climate changes over the last few centuries to determine if it is possible to predict changes for the next 200 years.

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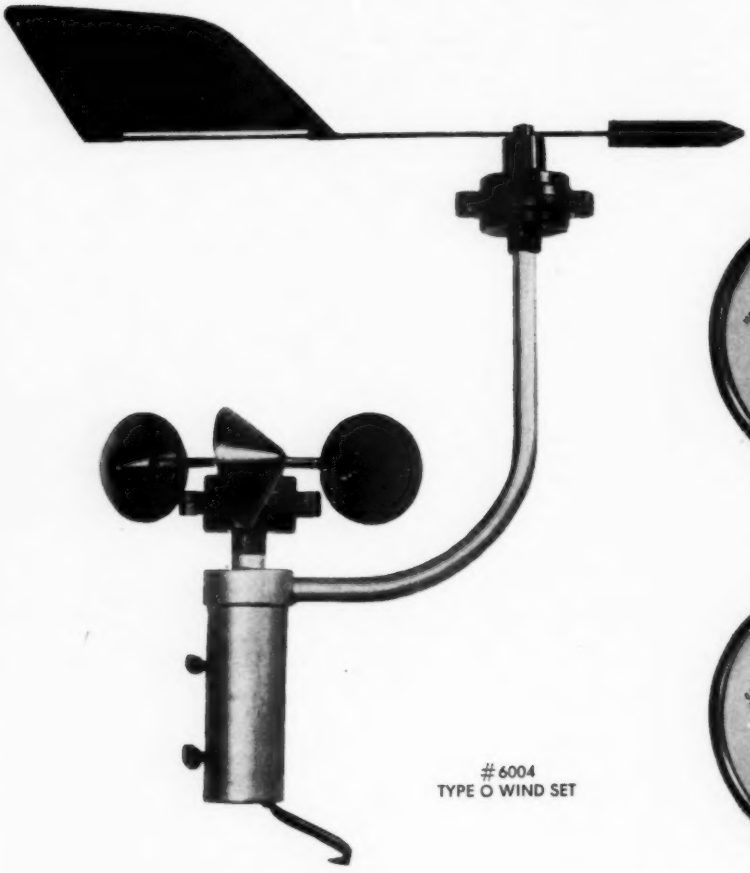


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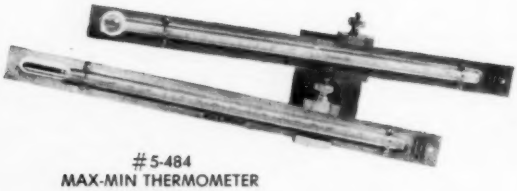

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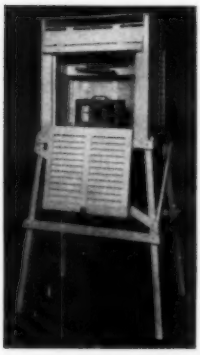

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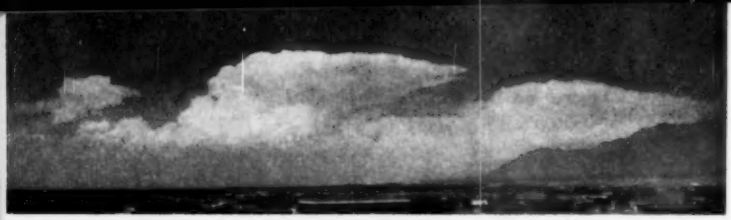


Photo No. 1. View NNE, 1310 MST, 13 July 1961.

Photo No. 2. View SSW, 1310 MST, 13 July 1961.

# Photos of Vertical Cloud Development Shear

WILLARD C. SNYDER,
*Hydraulics Section,*
*Corps of Engineers,*
*Albuquerque District*

THE photographs accompanying this article were taken on 13 July 1961, from downtown Albuquerque, New Mexico. All elevations are in feet above mean sea level. The elevation of the observer was about 5100 feet.

Photo No. 1 was taken at 1310 MST. Note the cumulus cloud top drifting well to the east in relation to the lower portion of the cloud. The cloud in the center is estimated to be about 40 miles from the observer, the cloud base is an estimated 20,000 feet, and the tops according to a radar report are 45,000 feet. The north end of the Sandia Mountains are on the right, and to give the reader a better perspective of distance, the ridge line of the mountains is 15 miles from the observer. The highest point on the ridge is about 10,000 ft.

Photo No. 2 was also taken at 1310 MST. Here again, note the cumulus cloud tops extending well to the east in relation to the lower portions of the clouds. Photo No. 3 is a composite of two photographs, and was taken at 1400 MST, and shows the extent of the easterly drift of the cloud tops in one hour. The Los Pinos Mountains on the extreme left of photo 3 are 55 miles away.

This type of cumulus cloud generally produces only a light shower at the most, and is not likely to develop into a thunderstorm. Much of the energy from the latent heat of vaporization is literally sheared off the top of the cloud as a result of much stronger winds near the tropopause than at lower levels.

The winds aloft at 1100 MST, 13 July 61:

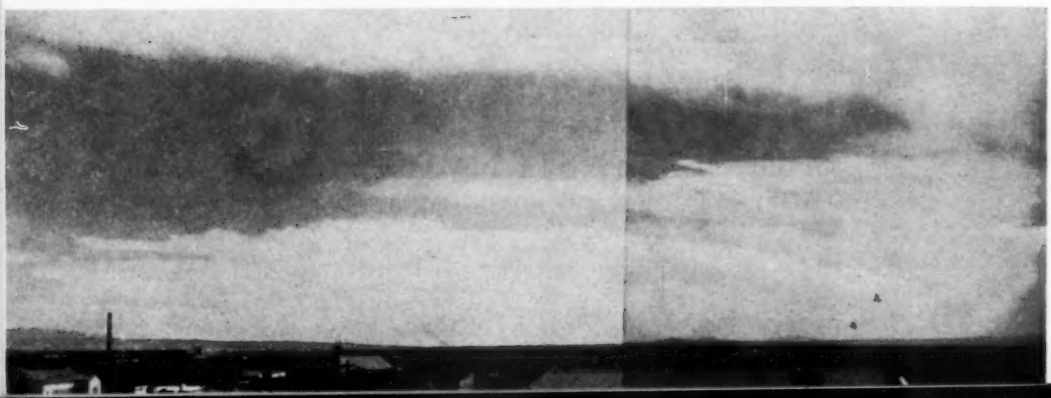
| Elevation | Direction | Knots | Elevation | Direction | Knots |
|---|---|---|---|---|---|
| 10,000 | W | 06 | 30,000 | WNW | 28 |
| 14,000 | NW | 21 | 35,000 | W | 29 |
| 20,000 | NNW | 32 | 40,000 | W | 48 |
| 25,000 | NW | 23 | 44,000 | W | 62 |

Note the speed shear from 35,000 to 40,000 feet, and from 40,000 to 44,000 feet, and that the speed at 44,000 feet is about double the speed at 35,000 feet and below.

Other pertinent data: (1) a double troposphere existed at 45,000 and 53,000 ft. (2) the jet stream was over northern New Mexico. (3) Radar reported cloud tops 45,000 ft. at 1500 MST.

Note that the cumulus cloud tops are at the level of the lower troposphere.

Photo No. 3. Composite view S, 1410 MST, 13 July 1961.



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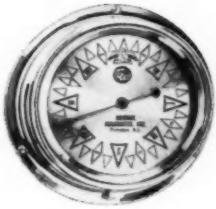

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